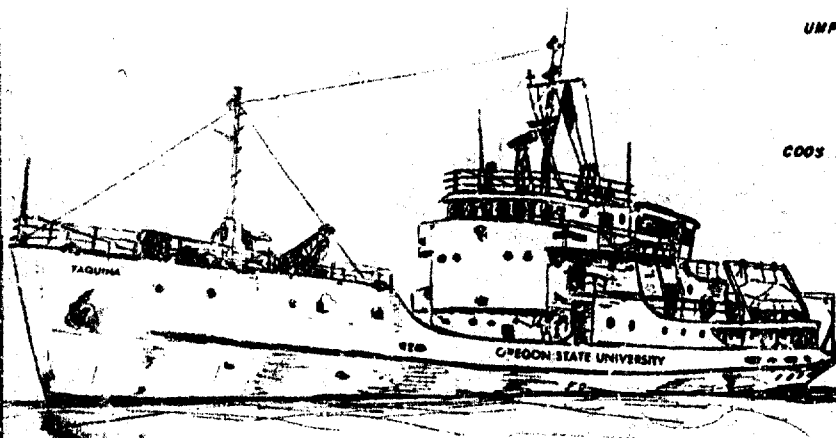


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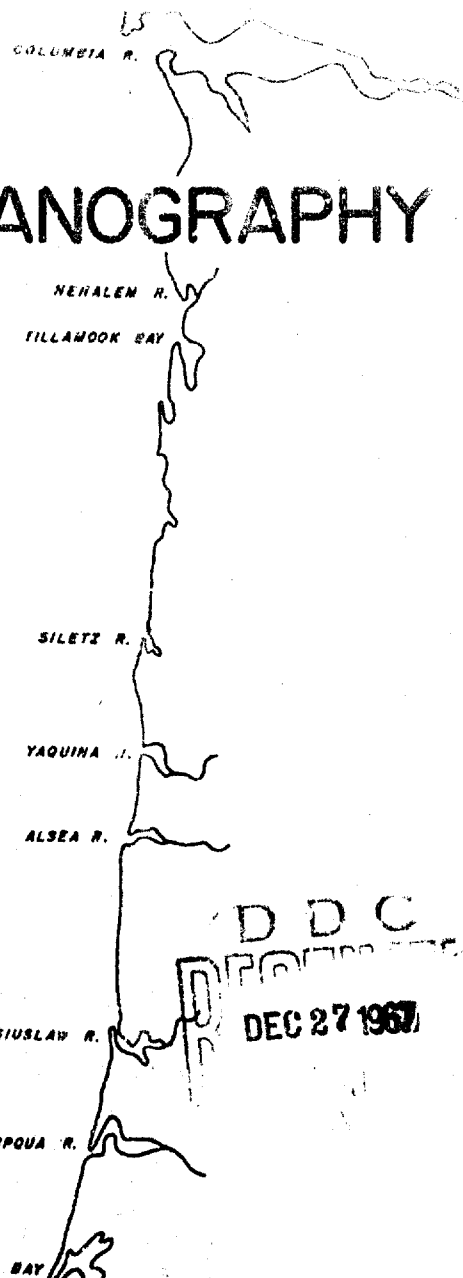
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## RESEARCH ACTIVITIES

1 April 1967  
through  
30 September 1967

Edited by

Sally Keiser  
and  
Diane Morton

Progress Report No. 20

Reference 67-14

Department of Oceanography  
School of Science  
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Corvallis, Oregon 97331

Herbert F. Frolander  
Acting Chairman

Progress Report No. 20

# RESEARCH ACTIVITIES

1 April 1967 through 30 September 1967

Edited by

Sally Kulm  
and  
Diane Merten

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## PHYSICAL OCEANOGRAPHY

### Atmospheric Effects on Incoming Solar Radiation in a Tropical Marine Environment - Quinn, Burt

A paper entitled "Weather and Solar Radiation Reception in the Equatorial Trough" has been accepted for publication in the Journal of Applied Meteorology. In this paper we have examined in some detail the weather and incoming solar radiation relationships during the unusual July 1957 through June 1958 weather period at Canton Island in the Equatorial Pacific (when Canton received nearly three times the normal amount of precipitation and experienced a 43 percent increase in mean total sky cover).

In a second paper, near completion, we consider the incoming solar radiation at Canton and Wake Islands and show the importance of actual cloud distributions (by type and amount) opposed to mean total sky cover when providing the cloud term entries of formulas for computation of incoming solar radiation. We further point out the likelihood that the incoming solar radiation over the tropical Pacific is greatly underestimated at present.

A third paper, in preparation, will evaluate currently available formulas for computation of incoming solar radiation by inserting various cloud cover entries. We also propose a suitable method for computing incoming solar radiation at locations where there is an unusually large cirriform contribution to the total sky cover.

### Research Buoy TOTEM IKT - Burt, Neshyba, Young

Scientists of several disciplines within the Department of Oceanography have increasing need for continuous meteorological measurements at points off the Oregon coast. Because the stable characteristics of a spar buoy make it one of the best known meteorological ocean platforms, such an oceanographic buoy, a 184 foot research buoy TOTEM IKT, has been built by members of this department (See Fig. 1) and initial sea tests have been completed. Mr. David Young, designer and construction supervisor, and Dr. Steve Neshyba, chief scientist, were extremely pleased with the buoy's performance despite severe weather conditions encountered at sea.

On Saturday, 9 September, the 30-ton buoy was towed to location in a horizontal position by the YAQUINA. The first night a sudden storm caused unscheduled filling of the TOTEM's ballast tanks. By morning the buoy had rotated to a vertical position. The storm abated sufficiently by Monday so that repair operations could be started by personnel aboard the YAQUINA and the PAIUTE. Divers found the damage was limited to the external area, and

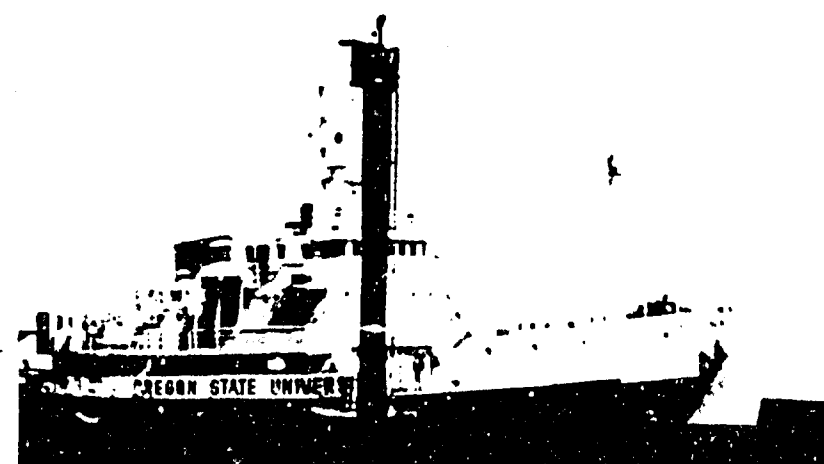
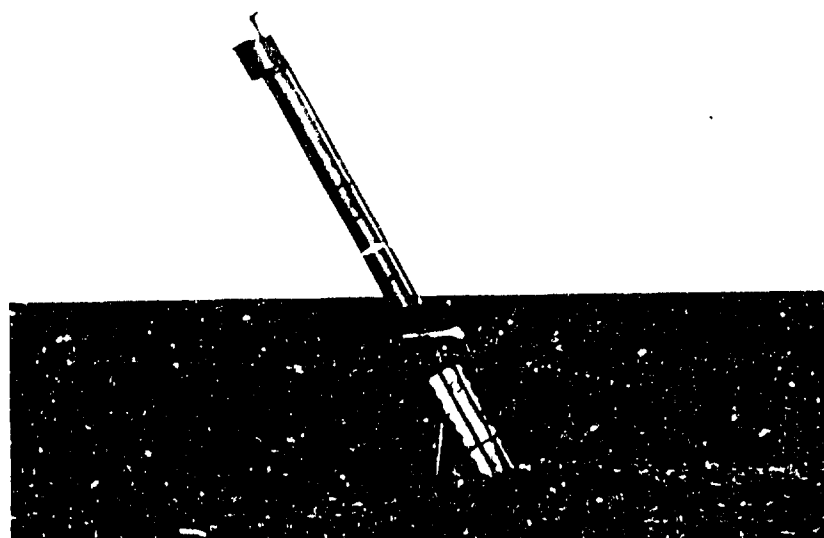
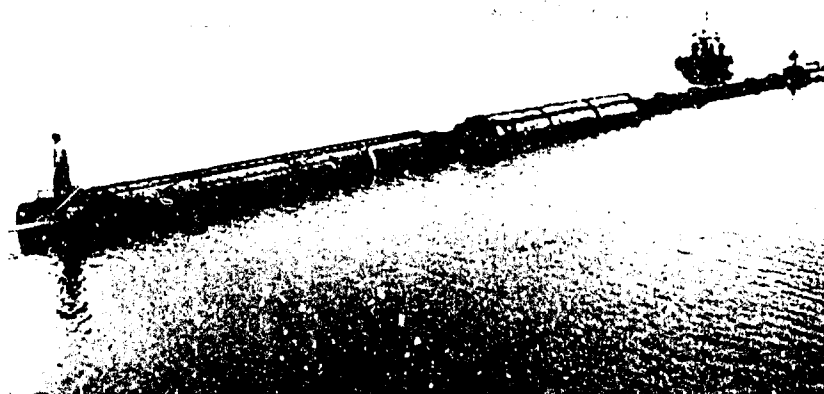


Figure 1. Research Buoy TOTEM IKT.



they were able to make the necessary repairs to unballast the buoy and return it to the horizontal position. The TOTEM returned under tow to Newport on late Wednesday.

After necessary modifications and additional mooring tests are completed, TOTEM IKT will be anchored about 20 - 30 miles off Newport. Initial tests involving meteorological data, now being planned, involve a careful study of differences in data between a shore station and a station at this distance from shore. The Department is now negotiating with the Naval Research Laboratory, Washington, D. C., for the loan of one or more Automatic Meteorological Stations. If the loan is effected, the first installation will be aboard TOTEM IKT.

#### Oceanic Temperature Measurements Across the Water-Sediment Interface - Mesecar, Burt, Bodvarsson

Dr. Mesecar wrote his doctoral dissertation on this research project. A portion of the abstract follows:

"A type of thermoprobe was designed and constructed to measure and record in situ oceanic temperatures to a precision of  $\pm 0.002^\circ \text{C}$  over a  $2^\circ \text{C}$  temperature span. The thermoprobe was used to measure temperatures 2.5 m into the sediment and 3.3 m above the ocean bottom interface for 19 stations west of Depoe Bay, Oregon. The station locations are distributed for the continental shelf, westward down the slope and out to 380 km from the coast on the abyssal plain.

A time-series analysis of 115 hours of temperature measurements on the continental shelf shows that the water temperature variations up to 3.3 m above the sediment have a large semidiurnal frequency component.

Down the continental slope, the sediment temperature gradients from eight stations are a linear function of the station depth and increase in magnitude with depth. Heat flow values for the slope follow a trend similar to the sediment temperature gradient.

For nine stations at the abyssal depth of 2800 m, the mean heat flow value is  $3.2 \times 10^{-6} \text{ cal cm}^{-2} \text{ sec}^{-1}$  with a variance of  $0.6 \times 10^{-6} \text{ cal cm}^{-2} \text{ sec}^{-1}$ . All these stations have superadiabatic gradients in the water up to 3 m above the interface . . . ."

#### Hydrographic Capability for the YAQUINA - Neshyba

Plans for the conversion of the dry lab on the YAQUINA into an electronics laboratory have been approved; transformation will take place during annual overhaul in December. The computer console with associated racks of electronics has been designed and ordered. The laboratory is scheduled to go into operation in January.

A study of the three major commercially available Continuous Profiling Systems, performed this summer, has resulted in the ordering of the Geodyne System for the YAQUINA. Delivery of the unit is expected about 1 December 1967.

A remote-controlled Fjarlie bottle sampler is being constructed here to supplement the Continuous Profiler. This unit will remotely sample the water column at three points during each CTD (Conductivity-Temperature-Depth) cast. The unit attaches to the CTD housing and is electronically controlled from the electronics laboratory.

The Department has allocated house funds to cover cost of services of a naval architect to design a CTD winch, hydraulically powered and controlled, but interchangeable between the R/V YAQUINA and the R/V CAYUSE.\* (The philosophy here is that the equipment is to be used from either ship on a minimum turn-around basis.)

Two deep-ocean remote recording current meters have been obtained from Geodyne Corporation. The associated gears required to make these current meters into free diving but recoverable units are under construction. A dual-time release mechanism is being constructed here, as are the housings for radio beacon, xenon lights, and other items. These two units are to be ready for operation some time during spring 1968. A joint hydro survey and sediment analysis program (by the marine geologists) of the Cascadia Basin is being planned.

GEK operations aboard the YAQUINA are now almost routine. We are in the process of constructing our own recorder to replace the unit now in use (on loan from the Naval Oceanographic Office). Several useful GEK runs have already been made in conjunction with the regular Newport hydrographic runs; plans call for this measurement to be a regular feature.

#### Themis Program - Neshyba

A project to study the use of computers in the data processing of meteorological and oceanographical data is the cooperative effort of the Oregon State University Computer Center and the Departments of Oceanography, Mathematics, and Electrical and Electronic Engineering.

The program, in its initial stages, calls for a series of instrumented buoys to be installed in a section of the ocean about 20-30 miles off Newport. The instruments will record information on wind, waves, weather, and water temperature and salinity. The data received will be transmitted to

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\*An 80-foot research vessel presently under construction for the Department of Oceanography, Oregon State University. (See page 52.)

a receiving station on shore, then relayed to the Computer Center at Corvallis. Results should lead to the successful prediction of local ocean response to various atmospheric conditions and of the interaction of atmospheric and ocean processes.

#### Weather Station at Newport - Burt, Neshyba, ESSA, Hedgpeth

A joint Oregon State University/Weather Bureau weather station is being placed into operation at the Marine Science Center, Newport, Oregon. Tentative date for initiation of operations is 1 November 1967. The Weather Bureau, ESSA, will supply a marine meteorologist of grade GS-12 to staff the center. To support the station, the Department of Oceanography is supplying the Facsimile, service teletypes, and other communications as well as office and station space within the Marine Science Center.

The broad objectives of the joint station are to perform research in the marine atmospheric environment and to improve Weather Bureau services for tourism, coastal communities, and research and operations at sea.

#### Tide Gauge Data - Pittock, Pattullo

The Fisher Porter recorder has operated well since installation in late January. Data for February, March, and April 1967 have been processed by the Coast and Geodetic Survey, ESSA, and copies are now in use by several researchers. Data available include gauge recordings at six-minute intervals, presently stored on magnetic tape; listings of hourly heights; and tabulations of derived values of mean sea level, mean higher high water, and others. An analog recorder in the museum section of the Marine Science Center provides visual display of the changing elevation of bay water.

#### Current Measurements in Shelf Waters - Collins, Pattullo

The first descriptive phase of this study has been completed. It was the subject of Dr. Collins' doctoral dissertation. His abstract is given below. A paper for submission to a scientific journal is in preparation. See also Oceanography of Shelf Waters.

"Currents and temperature were measured continuously above the continental shelf off Oregon during four periods lasting 25 days each. The data were obtained in July, September, and October of 1965 and in February 1966. Data are described using, where appropriate, elementary statistics, progressive vector diagrams, co-variance functions, and power spectra.

In July and September the waters above the Oregon continental shelf were well stratified and shear existed between currents at 20 and 60 m; this was true not only for the mean flow, but for low frequency and tidal

6

currents. In February, when conditions were nearly isopycnal between 50 and 75 m, currents at 50 m were similar to currents at 75 m for all frequencies studied.

Northerly currents were common and dominated September and October flow. In July, flow at 10, 20 and 60 m was usually to the south. Mean speeds varied from 13 cm sec<sup>-1</sup> to 27 cm sec<sup>-1</sup>. Flow was usually parallel to local topography.

Variations with a period of about one week dominated most low frequency (0 to 0.5 cpd) data. Low frequency variations of sea level and longshore velocity were in phase. A geostrophic current width of 75 km was obtained from the relationship between sea level and longshore velocity in July and September. For frequencies less than 0.2 cpd, sea level and longshore wind were in phase; an increase of one m sec<sup>-1</sup> of southerly wind was associated with a one cm rise of sea level.

Spectra of sea level had bands of energy at one and two cpd. Current velocity spectra had, in addition to significant one and two cpd energy, a peak at the inertial frequency, 1.4 cpd. Inertial currents were associated with storm passage. Temperature spectra for July, September, and October lacked well defined peaks at one and 1.4 cpd and were dominated by energy at two cpd. The amplitude of the two cpd temperature oscillation required considerable baroclinic response.

High frequency (7-144 cpd) temperature spectra had significant peaks near two and four cpd. Further, at a given depth, values of energy density were inversely proportional to the temperature gradient; this indicates that weak vertical stability enhanced high frequency oscillations."

#### Hydrography and Dynamics of the Alaskan Stream - Favorite, Pattullo

This study is continuing. Mr. Favorite was engaged full time in other work during these six months so there is little new material to report at this time. Active work will be resumed.

#### Water Masses Contributing to Oregon Coastal Waters - Blanton, Pattullo

Examination of hydrographic data off the West Coast of the United States has led to the discovery of a subsurface front extending from Point Conception, California, to Hawaii. This front may be related to, but is not identical with, surface and upper-level fronts previously described in this region. Characteristics of the waters on opposite sides of the fronts have been defined, and a descriptive model of the circulation has been proposed. Mr. Blanton is preparing his doctoral dissertation on the results of this research.

Seiching in Yaquina Bay - Gilbert, Fattullo

A technical-type report on the results of this study has been written. The abstract follows:

"The earliest work on seiche was of an observational nature dealing with its occurrence and appearance. This was followed by simple model studies based on simple theory. The first reports concerned seiche in lakes of simple shape.

As theory became refined and record analysis methods improved, these studies were extended to lakes of complicated topography and water bodies connected with the ocean. Present day studies often involve months of records which are subjected to spectral and harmonic analysis by computer.

This paper utilized two tide measuring instruments. The first was a permanent tide gauge mounted on a pier in Yaquina Bay. Several years of tide level graphs were available from this instrument so seasonal variations could be detected if they existed. A portable tide staff was also used to get accurate water level measurements of digital nature which were used in a spectral analysis. Before spectral analysis was performed on these data, the large period components (tide) and small period components (noise) were filtered from the data using a computer. Wind velocity, wind direction, barometric pressure at Newport, and geostrophic wind at sea were studied in conjunction with the spectral analysis results to determine possible seiche inducing mechanisms.

The simplest model of Yaquina Bay is that of an open ended trough of constant length and breadth. A standing wave's first mode of oscillation in such a basin would have nodes at either end and an anti-node at the center.

Permanent tide gauge records showed a prevalence of 10-16 minute and 22-26 minute period seiches during the summer months. Portable tide staff data verified the existence of 2-10 minute seiche occurring mostly during the winter.

The seiching was preceded by local winds from the west or by a frontal/high pressure passing at sea. Barometric fluctuations also preceded such activity, but seiching did not always occur after such a change. No large amplitude oscillations were observed; displacements were the order of centimeters to tens of centimeters throughout.

A study involving longer periods of accurate water level measurements taken simultaneously at several points in the bay would add more certainty to such a study."

Oceanography of Shelf Waters - Pattullo, Smith, Pillsbury, Mooers, Collins, Cuthin

A data report summarizing the first order statistics from the August-September 1966 current meter installation is in the final stages of preparation. It includes the results of four self-recording current meters and two thermographs which operated for 14 to 40 days at depths of 20 m and 60 m at offshore distances of 10, 20, and 30 kilometers in water depths ranging from 80 to 200 meters. Certain portions of the supporting hydrographic data are also included to give some indication of the state of upwelling and the position of the temperature inversion when the meters were embedded.

A subsurface, onshore-northward flow is indicated, a feature also detected at an anchor station 25 miles off Depoe Bay, Oregon, and on the continental shelf off Depoe Bay in the previous summer and autumn. Figure 2 shows a comparison of mean vertical profiles of velocity sampled hourly for 32 hours by various means (Eulerian and Lagrangian) in late September 1965. Sampling was done about 10 miles offshore. Notice the good agreement between sensors and the existence of a northward-onshore flow in the lower layer.

Two papers are in preparation which summarize some of our 1965 and 1966 measurements and which relate these to the dynamics of a coastal upwelling frontal zone.

A system of computer programs for data reduction and analysis is being developed with the aid of Mr. Walter Pawley. Their development is evolutionary because flexibility is maintained to allow the incorporation of checks, new ideas, and new calculations. Eventually the component programs will be operated as a system. Some recent additions have been the fast Fourier transform, general numerical taper, a new progressive vector diagram routine, kinetic energy and shear statistics programs.

The profile average program which is designed to operate on our "hydrographic data bank" is now on magnetic tape. It can compute the mean and standard deviation of sigma-t, temperature, and salinity for arbitrary classes of hydrographic line, offshore station(s), season, and depth. The standard deviation of the mean profile at a particular depth equals the plotted and tabulated value divided by the square root of the number of sample values.

Table I lists the plotted values and the sample size at each depth for samples taken over the period of 1961 through 1964.

Mr. Mooers' thesis work is proceeding along observational and theoretical lines. The correlation and spectral analyses of the August-September 1966 data are indicating the anticipated predominance of semi-diurnal phenomena. Further detailed examination is necessary to estimate wave parameters.

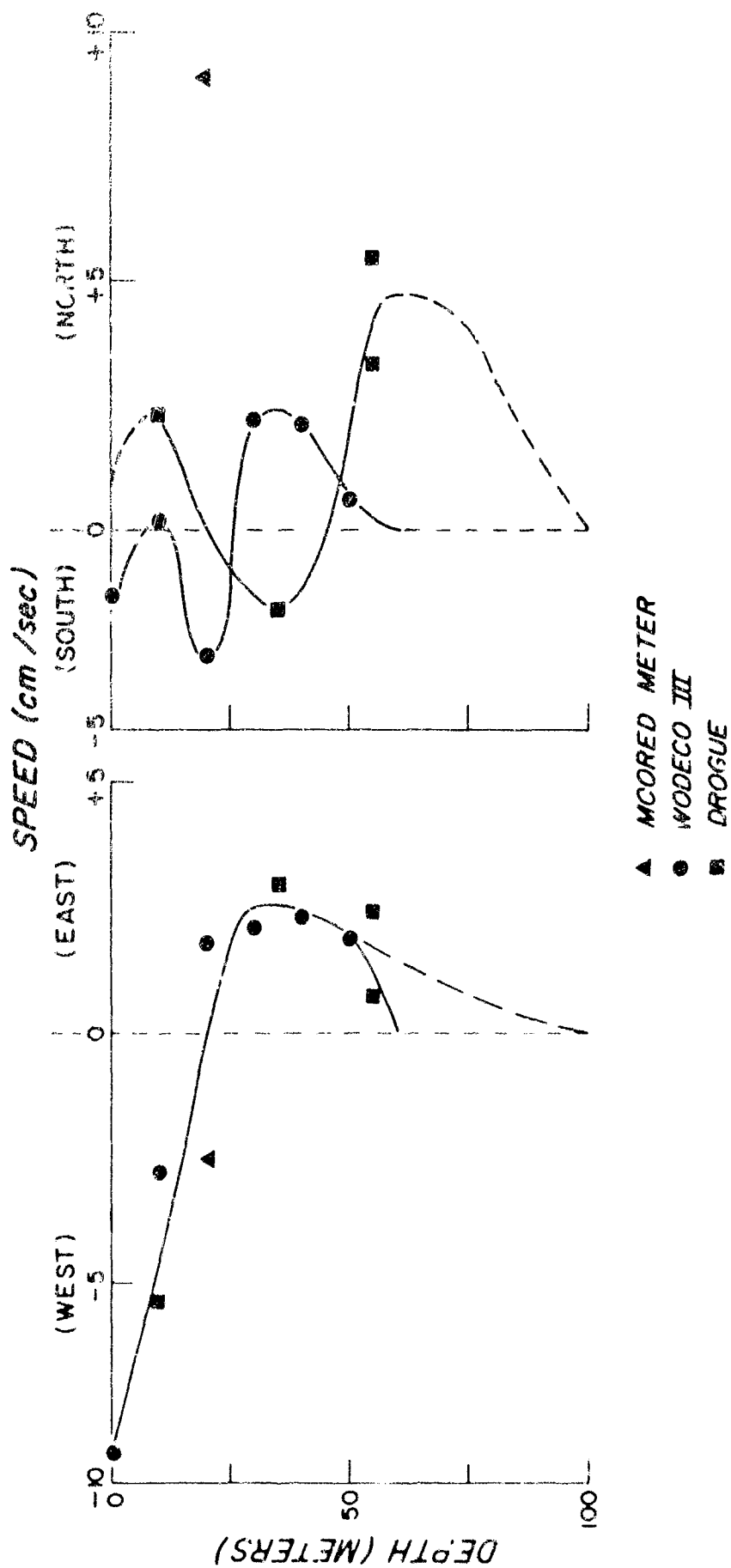


Figure 2. Comparison of mean vertical profiles of velocity off Depoe Bay, Oregon, in September 1965.

Table I. Plotted values of sigma-t and salinity, sample size, and depth of samples taken from 1961 through 1964 in Oregon continental shelf waters.

	Depth (meters)	$\sigma_t$	S	No.
December-February	5	24.96	0.13	18
	10	24.97	0.15	15
	20	24.97	0.19	7
	30	24.99	0.15	17
	50	25.15	0.25	21
	75	25.62	0.20	17
	100	26.05	0.14	20
	125	26.27	0.06	6
	150	26.38	0.07	17
	200	26.48	0.13	19
	250	26.62	0.01	2
	300	26.68	0.00	1
June-August	5	23.77	0.83	39
	10	24.20	0.65	34
	20	24.91	0.27	31
	30	25.16	0.20	35
	50	25.51	0.23	39
	75	26.03	0.17	28
	100	26.37	0.13	34
	125	26.52	0.09	4
	150	26.60	0.07	31
	200	26.68	0.10	33
	250	26.80	0.00	2
	300	No Data		

Anchor station hydrographic and current data at 25 and 40 miles offshore are being used to specify Cauchy data for the theoretical internal tidal wave propagation onto the continental shelf and into the array zone. The theoretical analysis has proceeded to the point of deriving mean flow-perturbation interaction terms, of analyzing by the method of characteristics, and of setting up the problem for finite difference solution. The prime objective is to determine zones of low dynamic stability based on the specification of density and mean flow field, of topography, and of Cauchy data along a vertical on the continental slope.



Hydrological Optics - Beardsley, Tucker, Carder, Hodgson, Pak, Zaneveld

The application of scattering and total extinction measurements to problems of descriptive oceanography has been developed into a doctoral dissertation by Mr. Pak. Considerable data is being accumulated, as optical measurements are now routine on all hydrographic cruises. Further data related to the location of the Columbia River plume have been obtained. To date all data have been reduced at the Oregon State University Computer Center. A new program written by Mr. Plank will enable us to use the ship-borne PDP-8/s computer to obtain reduced data at sea. Mr. Pak is beginning a study of the various possible methods of relating the data to other oceanographic parameters.

Preliminary tests of the feasibility of small angle scattering measurements from a laser source have been successfully completed at sea. Mr. Carder is now improving the apparatus so that polarization measurements of the scattered light can also be made. The preliminary comparisons of laser scattering versus incoherent scattering indicate that the laser measurements will be suitable for forward angle measurements and can be used with incoherent determinations of large angle scattering.

A preliminary investigation of the polarization of back-scattered light has been started by Mr. Hodgson. The object of this study is to determine the possible visibility improvement by using polarized sources.

Final calculations of visibility as a function of range, scattering albedo, and phase function shape were completed in late summer by Mr. Zaneveld. The results are being compiled for presentation to Naval Ordnance Test Station, Pasadena, California.

A Marine Advisers "alpha" meter has been modified to record in situ light transmissivity and pressure, making it possible to use the meter in conjunction with standard hydrographic casts. Our in situ spectrophotometer will be used at sea for the first time during our next optics cruise. It will be used with a small electric winch and several thousand feet of well-logging cable. Work is progressing on an improved laboratory scattering photometer to replace a Brice-Phoenix meter and on a meter which measures the polarization of the natural light field in the sea.

The radiative transfer program was completed and a set of parametric calculations made. The results of this work were presented at the September 1967 IUGG-IAPO meeting in Berne, Switzerland. The abstract is below.

"The scalar apparent optical properties of seawater are a set of seven measurables that describe the behavior of the submarine light field. These

properties are related to the inherent optical properties--the extinction coefficient and the scattering functions--through the equation of radiative transfer. Near the surface of the ocean, the apparent properties also depend upon the shape of the illuminating radiance, but with increasing depth they behave asymptotically.

A numerical approximation to the equation of transfer was programmed for solution on a high speed digital computer. The technique is based on resolving the hydrosol into a system of thin slabs, and then solving the transfer equation for each slab. No multiple scattering events are allowed in an individual slab. The method converges rapidly due to the relatively high absorption always present in natural hydrosols. The results of each set of calculations include the radiance solid, as well as the apparent optical properties, as a function of depth.

Calculations were made for a variety of typical seawater conditions by using a simple three parameter model for the scattering function. The scattering model is based on an empirical fit of scattering data from several locations, and it retains the highly directional characteristic typical of the phase function of natural hydrosols. The results, presented in both graphic and tabular form, allow one to predict the submarine light field at a given location if the two inherent optical properties and the incident daylight radiance field are known."

#### Boundary Kinematics - Beardsley, Earle, Plank

The latest cruise for air-sea studies included a test of radio telemetry of wave and wave velocity data. Although the transducers and transmitters functioned as desired, the noise at the receiver was so great that useful records could not be obtained. As a result of this cruise and further experiments in the lab, we decided to return to the use of a floating multi-conductor cable for our data link. Mr. Earle has completed a three-channel system which is now being tested on a small wave pole (a 20-foot pole with a 6-inch diameter). This system will be used on the next major air-sea cruise for studies with wave height, wave pressure, and wave velocity probes.

The bulk of the digitizing and control components have arrived, including a PDP 8/s computer that forms the heart of the system. The major item remaining on order is the incremental tape recorder. The equipment is being assembled and debugged, and programs are being prepared by Mr. Plank. It is hoped that the first sea tests of the system can be made on the November air-sea cruise.

Air-Sea Interaction - Pond, Gorner, Mesecar

A program for measuring the turbulent fluxes of momentum, sensible heat, and water vapor and the gradients of wind speed, temperature, and humidity is being undertaken.

All data will be recorded on magnetic tape. The recording equipment is on order as are the cup anemometers. Equipment for measuring temperature (wet and dry bulb) gradients is being tested; flux measuring equipment is being planned.

The initial measurements will be made just off the coast at Newport. Designs for an instrument tower to transmit signals to the Marine Science Center for recording are now being considered. The initial measurements will be mainly for instrument and system testing and development. Eventually measurements will be made farther offshore.

Upwelling Along the Southeast Arabian Coast During the Monsoons - Smith, Bottero

The horizontal and vertical fields of motion along the Southeast Arabian coast during the monsoons are being studied. A paper on the results of studies to date was given by Dr. Smith at the IAPO/IUGG meeting in Switzerland 28 September 1967. The abstract follows:

"Under the assumption that the horizontal motion is composed of 1) a geostrophic flow prescribed by the slope of the sea surface and the density distribution and 2) an Ekman flow in the surface layer, the horizontal and vertical field of motion along the SE Arabian coast during the SW monsoon is computed. Using data from R. R. S. Discovery Cruise I, which surveyed the SE Arabian coast upwelling region in June to August 1963, the relative geostrophic and Ekman transports are computed. The topography of the sea surface, which is necessary to compute the absolute transports, is found by the method Wyrski used in his study of the Peru Current upwelling region (Bull. Scripps Inst. Oceanography 8: 313-346, 1963). This method equivalently defines levels of no motion and the levels found are compared with those determined by DeFant's method. The level of no motion in the southern part of the region is between 900 and 1000 db, the two methods being in agreement. In the north the agreement is less good. The wind stress computed from the shipboard wind velocity observations using the usual square law are in good agreement with those computed by Hidaka for this season and location (Rec. Ocean Wks in Japan 4: 77-123, 1958). Coastal upwelling occurs along 1000 km of the coast and may amount to as much as  $10 \times 10^6 \text{ m}^3/\text{sec}$ ."

Future work will consider the effects of various averaging and smoothing of the hydrographic and meteorological data. A comparison of results of

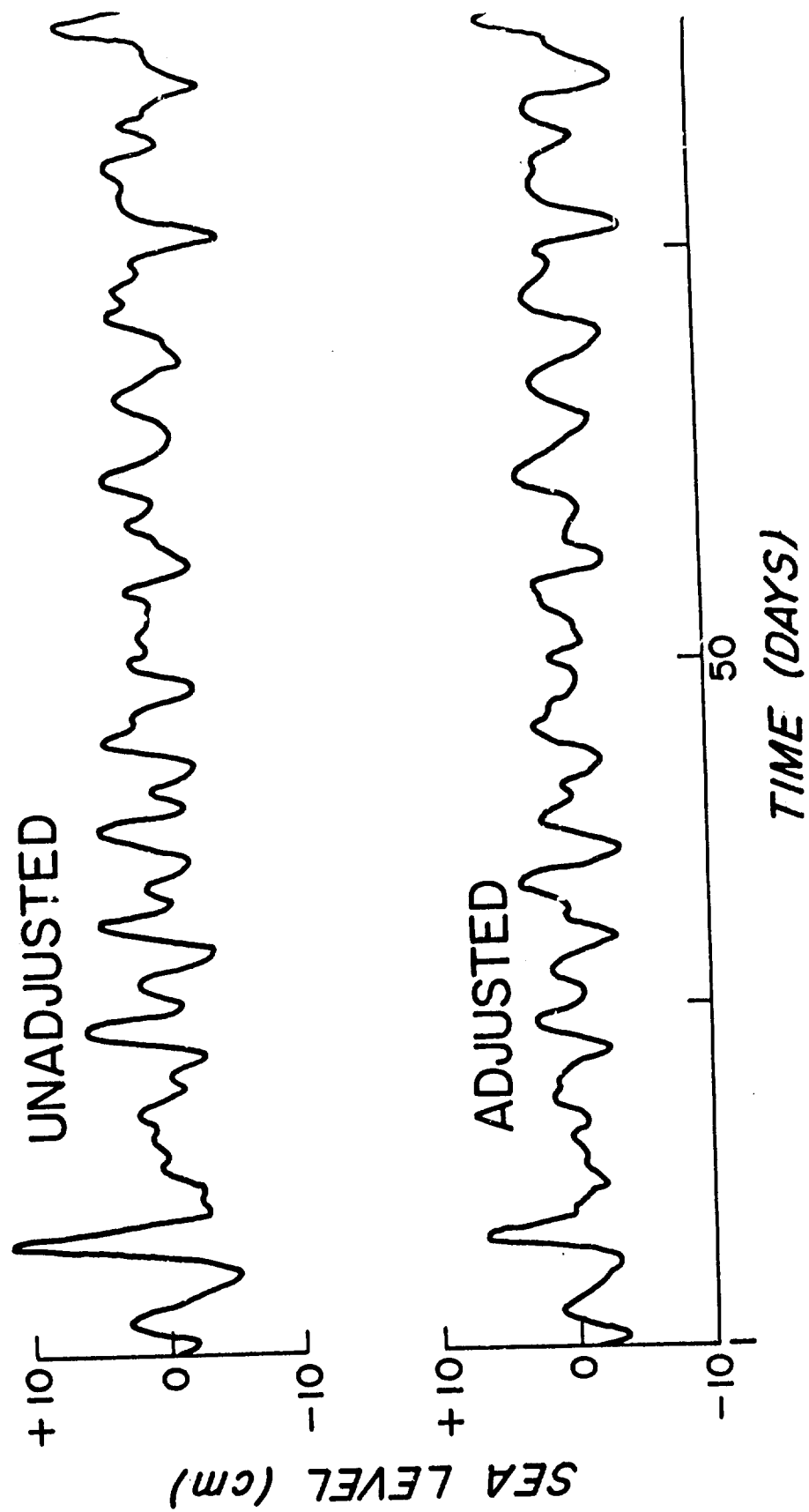


Figure 3. Adjusted and unadjusted sea level for Coos Bay, Oregon.

calculations will be made with direct current measurements made by the RRS DISCOVERY.

#### Sea Level Studies - Mooers, Smith

A paper on this work has been accepted for publication. The abstract of the manuscript is given below:

"A statistical search for continental shelf waves of several-day periods has been performed on Oregon sea level records. Daily mean sea level at three locations, atmospheric pressure, and winds for winter and summer 100-day records have been analyzed by using standard correlation and spectral analysis techniques. The summer atmospheric pressure and sea level spectra have peaks at 0.1 and 0.3 cycles per day. The sea level records have been adjusted for a one-to-one isostatic barometric factor, yet there remains a strong coupling between atmospheric pressure and sea level at frequencies of 0.1 and 0.35 cpd in the summer. Computations from cross-spectra give a barometric factor of about -1.2 cm/mb. The cross-spectral analysis indicates a wave at 0.1 cpd moving to the south with the atmospheric pressure systems and a wave at 0.35 cpd moving to the north as a free continental shelf wave. The wave phenomenon at 0.35 cpd is consistent with the theory of continental shelf waves and with similar observations on the Australian shelf."

Figure 3 shows summer 1933 low-pass tapered sea level data for Coos Bay, Oregon. The adjusted record has had the in-phase, isostatic effect of atmospheric pressure removed. There are motions with periods of 3-10 days and with amplitudes of 0.5-5 centimeters in the data. These data are part of the basis for the subsequent analyses in the paper.

Work has begun on the determination of the frequency domain response of sea level to both winds and atmospheric pressure. This work has required examination of both local, direct wind observations for North Bend, Oregon, 1933-1934 and areal, geostrophic wind estimates. We are predicting, in the pass band of 0.05-0.5 cycles per day, sea level and eventually current data using atmospheric inputs. We think an interesting and important scale of observable phenomena may exist in this frequency band and may play a role in coastal upwelling.

#### Hydrography of Oregon Waters - Wyatt, Pattallo, Still, Barstow

Monthly hydrographic cruises were continued off Oregon with particular emphasis placed on the Newport line. Stations from 5 to 165 miles west of Newport were monitored to determine the salinity, temperature, oxygen, and phosphate content of the seawater. Biological collections were taken with vertical meter net trawls and midwater meter nets. Cruise dates and samples taken are summarized in Table II.

Table II. Samples taken at 5, 15, 25, 35, 45, 65, 85, 105,  
125, 145 and 165 miles west of Newport.

Cruise Dates 1967	Nansen Casts	T °C	S ‰	O <sub>2</sub>	PO <sub>4</sub>	iKMW Trawl	Vert. meter net tow	BT casts
April 10 to April 13	11	X	X	X	X	5	1	55
May 7 to May 13	49	X	X	X	X	5	4	70
June 2 to June 6	17	X	X	X	X	19	7	22
July 5 to July 15	12	X	X	X	X	-	-	20
August 29 to August 31	12	X	X	X	X	-	-	71

## GEOLOGICAL OCEANOGRAPHY

### Continental Margin

An extensive investigation of the continental margin off southern Oregon (Coos Bay to the Oregon-California border) is currently underway. This three-dimensional study includes structure, stratigraphy, sedimentation, and potential economic placer deposits of the area.

#### Bathymetry - Kulm, Spigai

Approximately 650 nautical miles of north-south and east-west echo sounding track lines have been run on the southern Oregon continental shelf and slope (between Cape Blanco and the Oregon-California border). These soundings will be integrated with those from existing surveys by the United States Coast and Geodetic Survey. Several structural benches were delineated in the echo sounding survey.

#### Sediments - Kulm, Fowler, Buehrig, Chambers, Spigai

The surface sediment pattern off southern Oregon is now known in some detail. A total of 157 Shipek samples were collected this summer and the analyses of these sediments are in progress. Both textural and mineralogical compositions of the sediments will be determined.

Fifty-two box cores (maximum penetration is 18 inches) were collected in the vicinity of the Rogue and Sixes Rivers. Most of these cores were sampled quantitatively onboard ship and will be analyzed for their texture, mineralogy, and heavy metal content. A sediment facies map has been drawn on the basis of a cursory field inspection of the sediment texture of these cores. A sand facies (greater than 75 percent sand), which is commonly interrupted by rocky areas, occurs between the present day beach and a depth of about 35 fathoms. A mud facies (less than 50 percent sand), only a few inches in thickness, exists on the central part of the shelf between approximately 35 and 70 fathoms. A muddy sand facies (50 to 75 percent sand) is found below the mud facies and extends to the outer edge of the continental shelf. A sand facies occurs below the muddy sand facies on the outer shelf and is undoubtedly relict Pleistocene sand.

Microfauna and megafauna assemblages that occur in a shallow layer found at the bottom of a 16-inch box core, taken at 90 fathoms, indicate a paleodepth of approximately 15 to 25 fathoms (inner sublittoral zone). The possibility that a Late Pleistocene beach exists at approximately 70 fathoms is being investigated.

Nineteen piston cores were taken on the outer continental shelf and upper continental slope. These cores ranged in length from 1 to 6 meters

and commonly contained fine-grained sediments; coarse sand and gravel were collected in a few cores.

#### Stratigraphy - Fowler, McKeel

A total of 11 pipe dredges and 2 rock cores have been taken on the continental shelf and slope off southern Oregon. Most of the samples come from the vicinity of the Coquille River where numerous rock exposures occur. The sedimentary rocks currently are being analyzed for their faunal content so that their age and environment of deposition can be determined.

#### Structure - Kulm, Bales, Mackay, Fowler

Approximately 565 nautical miles of continuous seismic profile lines were run between Coos Bay and the Oregon-California border. A 5,000 joule EG&G sparker was used for the survey. Most lines run across the continental shelf in an east-west direction and are spaced approximately 5 nautical miles apart. Several "tie" lines were run in a north-south direction. The profiling was concentrated in areas where buried stream channels were suspected.

A preliminary analysis of the sparker records shows that the continental shelf off southern Oregon is characterized by intense folding and faulting and marked angular unconformities. The present configuration of the shelf and upper continental slope appears to be largely tectonic in origin.

#### Camera Studies - Kulm, Neudeck, Buehrig

Twenty-two camera stations (thirteen in stereo) were occupied on the continental shelf and upper slope between Coos Bay and the vicinity of the Rogue River. Negatives of these pictures have been developed, and they are being edited for printing. It is hoped that these photographs will aid us in determining the nature of the sea floor in selected areas.

#### Foraminiferal Ecology - Fowler, Boettcher

A thesis covering the study of shelf foraminifers from the area between Cape Arago and the Siuslaw River has been completed.

#### Yaquina Bay Foraminifera - Fowler, Manske

The areal and seasonal study of foraminifera in Yaquina Bay has been completed and a final report is being prepared. Species association studies from the Fager-McConnaughey correlation coefficient method indicate that a marine biofacies fauna dominated by Elphidium spp. occupies the main estuary channel as far upstream as the vicinity of Oneatta Point. The penetration of this fauna is somewhat greater during the winter, a



result of the change in salinity structure and circulation pattern during this season. In addition the marine biofacies zone tends to be more restricted to the main estuary channel during the winter than is the case for the summer. In the lower bay, the Elphidium fauna is displaced laterally by an assemblage characterized by Trochammina charlottensis and Elphidium incertum in the mid-intertidal zone. The upper-intertidal area is populated by an Ammobaculites-Miliammina fauna. Upstream the Elphidium assemblage gives way to a Miliammina fauna. Trochammina inflata, T. macrescens, Jadammina polystoma, Haplophragmoides hancocki, H. sp., Siphotrochammina sp., and Miliammina are the principal representatives of the high marsh assemblage.

Species diversity ranges from 22/sample in the marine biofacies zone to 6/sample on the lower bay tideflats. The areas of highest standing crops are the marshes (summer) and the tideflats adjacent to the lower bay channel, averaging 40 and 42/cm<sup>2</sup>, respectively. Lowest values (1-2/cm<sup>2</sup>) were noted for the mid-to upper-intertidal areas of the lower bay during the summer. Based on foraminiferal evidence, the highest rate of deposition occurs on the mid-intertidal area of the lower bay tideflats during the winter. The area undergoing the least sedimentation appears to be that of the marine marsh.

### Deep Sea

#### Astoria Canyon - Byrne, Carlson

A doctoral dissertation on the "Marine Geology of the Astoria Submarine Canyon" has been completed by Paul R. Carlson. An abstract of this dissertation is given below.

"Astoria Submarine Canyon begins nine miles west of the Columbia River at a depth of 55 fathoms and winds sinuously southwestward across the continental terrace for a distance of 65 miles to a depth of 1140 fathoms. At this depth the canyon hooks sharply to the left and the morphologic characteristics change to those of a deep-sea channel (Astoria Channel) which continues across Astoria Fan. Eight distributary-like channels radiate across the fan from the mouth of Astoria Canyon.

This canyon has U- to V-shaped transverse profiles, high, fairly steep walls with rock outcrops, a winding course and numerous tributaries entering the canyon from both sides. It is more like Willapa and Hudson Canyons in morphology and sediment type than any of the other submarine canyons that have been studied in any detail. Between the head of Astoria Canyon and the mouth of the Columbia River, several buried channels have been detected which suggest the importance of the Columbia River in cutting or at least shaping the head of the canyon during lower stands of sea level.

Based on the estimated volume of sediments of Astoria Fan and the sediments contributed by the Columbia River and by littoral transport, an age of late Pliocene to early Pleistocene is hypothesized for the inception of the Astoria Canyon-Fan system. Turbidity currents, bottom currents, mass movements and the burrowing actions of benthic organisms were important agents of submarine erosion. Step-like offsets of the canyon's axial trend plus offset sedimentary basins north and south of the canyon suggest the influence of tectonic activity on the location and orientation of the canyon.

The sediments and semi-consolidated sediments of the canyon area are of late Pliocene to Recent age. Coarse layers which range in mean particle size from fine sand to medium silt are more abundant deep in the canyon floor sediments than at the surface, suggesting a greater influx of turbidity currents during the Pleistocene than in postglacial time. These coarse layers are poorly sorted, graded and contain displaced shallow water benthic foraminifers. The mineralogy of these coarse layers closely resembles the mineralogy of Columbia River sediments, a fact which emphasizes the importance of the sediment contributions of this river. The surface sediments in the canyon area range from sandy muds high in plant fragments near the canyon head to hemi-pelagic silty clays at the lower end of the canyon. Along the rim of the canyon near the edge of the shelf, relict sands which have textural characteristics similar to inner shelf sands occur in patches at the surface. At the outer edge of the shelf and on the upper slope, glauconite makes up a significant part of the sediment.

Although Astoria Canyon was an important route for turbidity currents during the Pleistocene, it no longer functions in this role. Since the last rise of sea level when the zone of longshore transport moved eastward of the present canyon head, Astoria Canyon has been filling. Rates of deposition in the canyon area, based on radiocarbon dates, occurrence of Mazama volcanic glass, and changes in the ratio of radiolarians to planktonic foraminifers, range from 10 cm/1000 years in tributaries to more than 50 cm/1000 years in tributaries to more than 50 cm/1000 years on the canyon floor which, if unchanged, could fill the canyon in less than eight million years.

Canyon geometry, facies relationships and sediment characteristics of modern submarine canyons are criteria useful in the identification of canyons in the geologic record."

#### Astoria Fan - Byrne, Kulm, Nelson

The study of the bathymetry and sediments of Astoria Fan is nearing completion. This study will provide invaluable information as to the sedimentary framework of Cascadia Abyssal Plain.

Cascadia Channel - Kulm, Griggs

The bathymetric surveys and sediment sampling program has been completed for that portion of Cascadia Channel which traverses Cascadia Abyssal Plain. Twenty-three piston cores were taken in May, which bring the total to 46 cores taken in the Channel to date. These piston cores have been taken from the channel floor, walls, banks, and tributaries in order to complete the sedimentation picture of Cascadia Channel. In addition, 891 nautical miles of echo sounding lines were run across the channel at this time. Extensive cross-channel profiles have been completed from the channel's origin at the base of the continental slope to its passage through the Blanco Fracture zone.

All piston cores collected in the channel to date have been opened, photographed, logged, and sampled. A paper is being prepared for publication on the burrow mottling in the cores from Cascadia Channel and vicinity.

Cascadia Abyssal Plain (Cascadia Basin) - Kulm, Fowler, Duncan, Griggs, Buehrig

A paper on this research was given at the Society of Economic Paleontologists and Mineralogists meeting in Los Angeles, April 1967. The abstract follows:

"Deep-sea channel and interchannel deposits from the southern portion of Cascadia Abyssal Plain have been studied through textural and coarse fraction analyses, fauna, radiocarbon dating, and stratigraphic sequence. Piston cores were taken along a line from the base of the continental slope off central Oregon to the western edge of the abyssal plain.

Faunal and color changes between the upper and lower sections of several cores represent a significant stratigraphic horizon (a change from glacial to postglacial conditions). The ratio of planktonic foraminifers to radiolarians is less than one above the horizon and greater than one below. The radiocarbon age of the deposits immediately below the horizon is 15,200 B. P.

Both channel and interchannel sediments show a marked increase in the number and thickness of sand layers deposited during glacial time, while postglacial deposits display a decrease in sands. Only postglacial deposits have been observed in Cascadia and Astoria channels and in the interchannel area to the east of the latter. The coarsest layers in these channels consist of coarse silt and very fine sand, respectively. Two unnamed channels on the western side of the plain display a largely glacial section consisting chiefly of very fine sand and coarse silt. Interchannel deposits on the western edge of the plain are significantly finer-grained than those on the east.

The highest rates of sedimentation in the area apparently occurred during glacial time. Radiocarbon dates indicate a rate of accumulation during glacial time of about 170 cm/1000 years for an interchannel area on the western edge of the plain. Postglacial rates of deposition are highest on the eastern side of the plain, particularly in the area adjacent to the continental slope, and in Astoria and Cascadia channels."

## GEOPHYSICAL OCEANOGRAPHY

### Marine Gravity - Banks, Couch, Gemperle, Skorpen

Two free-air gravity anomaly maps--Columbia River to Cape Cook and Cape Cook to Dixon Entrance--have been prepared from approximately 10,000 gravity stations west of British Columbia and Washington. These maps indicate the presence of a large negative gravity anomaly, approximately 100 miles in length and 20 miles in width, along the west coast of northern Vancouver Island.

Two crust and subcrustal cross sections across the Juan de Fuca Ridge, Cascadia Abyssal Plain, the state of Oregon, and western half of Idaho have been prepared from seismic refraction and gravity data obtained since 1963. These sections suggest that the Juan de Fuca Ridge is the expression of a low-density ridge in the mantle that lies within a mantle province of a lesser low-density material.

Analyses of seismic refraction and gravity data are continuing in our effort to study the structures of the crust and the subcrust in the region west of Oregon, Washington and British Columbia.

Along the Inside Passage of Alaska and British Columbia, 104 selected gravity stations have been reduced to isostatic gravity anomalies to determine the extent and magnitude of the isostatic imbalance of this glacially scoured land. The analysis of this reduced data is continuing.

Analysis of the magnetic measurements made during the YALOC-66 cruise across the Aleutian Ridge and Trench near Adak, Alaska, have been completed and presented in the form of a thesis.

Additional gravity and magnetic measurements have been made west of Oregon and northern California. After reduction these measurements will be incorporated into an updated map of this region.

### Earthquake Seismology - French, Gallagher, Couch

The World-Wide Seismic Station at Corvallis, Oregon, and the satellite station at Klamath Falls, Oregon, have been operated continuously during this period.

Theoretical results for head-wave amplitudes have been put into a form useful for numerical calculation. A computer program (for CDC-3300) has been written to study the effect of crustal parameters on the amplitudes of converted waves which travel in part as head-waves. Seismograms are being analyzed on the basis of these results for the determination of focal depth, crustal structure in the near-source and near-station regions, and radiation patterns from local earthquakes.

CDC-3300 computer programs have been written to compute epicentral distance, azimuth, back-azimuth between seismic stations and epicenters; to determine the effect of different crustal models on rays leaving the source; and to determine fault plane solutions possible from the available data.

P and S wave data are now being tabulated for over twenty small earthquakes of northwestern North America. Comparison of existing fault-plane solutions of large earthquakes with the new solutions will be used to establish statistical criteria on best fit of fault planes with regard to onsets, amplitudes of waves and number and geographic distribution of stations.

Interpretation and Reduction of Ocean Floor Heat Flow Data - Bodvarsson, Shih

Theoretical research on ocean floor heat flow anomalies has been carried out based on the solution of the heat transport equation for various models. The effects of (1) irregular bottom topography, (2) variable thickness of sediments, (3) inhomogeneous conductivity in the basement, and (4) intrusion of magma have been investigated. Disturbances due to instrument effects have been taken into account. Moreover, climatic influences on the ocean floor temperature have been estimated on the basis of eddy diffusion models for the thermo-haline circulation.

Electrical Conductivity of Lava and Exploration of Geothermal Anomalies with Electrical Methods - Bodvarsson, Mathews

Field measurements on the electrical conductivity of lava from Mount Etna in Sicily will be carried out during October 1967. The data will be used as a basis for an investigation of possibilities of applying geoelectrical methods in the prospecting for natural heat resources.

Physics and Geochemistry of Thermal Areas - Bodvarsson

Heat transport and heat accumulation in geothermal areas have been studied on the basis of theoretical models and field data from various parts of the world. Research is being carried out on the possibilities of using the concentration of free hydrogen in natural steam as a geochemical temperature indicator. Direct hydrological interpretation methods are being applied to a geothermal area in Iceland.

Direct Interpretation Methods in Geophysics, with Special Emphasis on Marine Magnetic Fields - Bodvarsson, Emilia

Direct interpretation methods are being applied to marine geophysical data from the Atlantic and the Pacific Oceans. The magnetization of the source rock is being computed directly on the basis of the field data. The object of this research is to derive practical methods of solving the convolution integral equation for the magnetization. Standard numerical techniques, the

Fourier transform method, and the linear programming method are being investigated.

Temperature Microstructure and Eddy Transport in the Ocean Floor Boundary Layer - Bodvarsson, Korgen

Research is in progress on the detailed temperature structure and on the currents within the ocean floor boundary layer in deep water off the Oregon coast. Using a modified Bullard-type heat probe with thermistors attached to an above-bottom vertical angle iron, we are measuring the temperature at 8 points over a 5-meter interval. Usually, three measurements are within the sediments and five measurements are above the ocean floor. The results give both temperature gradients and corresponding heat flows when the thermal conductivity of the sediment cores also taken are considered. From both the T gradients and the heat flows, the corresponding eddy transport coefficients are estimated.

In addition, a prototype bottom-current meter has been constructed which will measure currents in the deep boundary layer at two points which are a fixed distance apart. This instrument, firmly planted in the ocean floor, takes a core to reveal its orientation with respect to the bottom interface. The latter instrument is being tested at sea, and research will progress to relate the observed diffusivities with the current velocities measured in the deep boundary layer.

Paleomagnetic Studies - Heinrichs, McKnight

Components of the new demagnetization apparatus and Spinner magnetometer have arrived and are being assembled. A computer program is being written for complete analysis of data by using initial magnetometer measurements. Samples for paleomagnetic analysis have been obtained this summer from Recent lavas in the McKenzie Pass area and from Pliocene flows near Silver Peak, Nevada.

Land Gravity - Heinrichs, Thiruvathukal

From 1962 to 1966, a broad gravity program has been underway which consists of establishing gravity base station control and compiling data for more than 8000 gravity measurements made in Oregon. This project is now complete.

Free-air and Bouguer anomaly maps of Oregon have been constructed and have been published by the Oregon State Department of Geology and Mineral Industries (Scale: 1:500,000). Several distinctive features of the Bouguer gravity map are (1) a generally decreasing gravity field toward the southeast, probably related to major variations in regional geology such as an increasing crustal thickness in the southeastern part of Oregon; (2) a

steep gravity gradient about 50 miles east of the coast indicating a major structural feature; (3) a lack of expression for the Cascade Mountain Range; and (4) isolated gravity highs and lows in the area of Plio-Pleistocene volcanism.

The final analysis of the gravity anomalies and their interpretation in terms of both regional and local geology of the state is completed. The data were also used in the investigation of different techniques for determining regional and residual anomalies. The results of this work are now being prepared for publication.



## CHEMICAL OCEANOGRAPHY

Improvement of Shipboard Technique - Park, Ball, Bradford, Cissell, Gordon, Hager

Nutrients - Mr. Hager has measured silicate in the surface waters of the Columbia River plume region using the Technicon Autoanalyzer which provides a continuous recording. Mr. Hager, Mr. Gordon, and Mr. Cissell are continuing the assembly and adaptation of the Autoanalyzer for phosphate, nitrate, and iron analyses.

Cations - Mr. Bradford has performed analyses at sea for calcium in seawater using the calcium-sensitive membrane electrode. Results of analyses of 95 seawater samples were compared with the results of analyses of the same waters by atomic absorption and flame spectrophotometry. The comparison is encouraging but indicates that further work is required on the response and selectivity of the electrode as a function of the ionic strength of the seawater, calibration and reproducibility of the electrode, and the effect of higher quality electronics on the overall performance of the system.

Carbon Dioxide - Support has just been received for a system including an infra-red carbon dioxide analyzer and an air-water equilibrator. Mr. Ball is pursuing this work.

Columbia River Plume and Coastal Upwelling - Park, Bradford, Catalfomo, Cissell, Gordon, Hager

The main purpose of a 10-day cruise in July aboard the R/V YAQUINA was to study the chemical characteristics of the Columbia River plume in the region from Astoria, Oregon, south to Crescent City, California, and to a distance of 340 miles west of Crescent City. The specific objectives accomplished in increasing importance were the following:

1. Precise alkalinity, total CO<sub>2</sub>, and nutrient relationships at five deep-sea stations.
2. Effects of upwelling along the coast off Oregon. The effects of the upwelling on the biological productivity were found to be pronounced as shown by the intense oxygen supersaturation, high pH's, and lowered total CO<sub>2</sub> as observed in the region near the upwelling.
3. Determination of size and strength of the plume area. If the 32.5‰ contour of the surface salinity data was used as a rough estimate of the boundary of the plume area, then the Columbia River plume was well developed to the extent of 42° S and 130° W. Each of the remaining variables measured correlates strikingly with the plume area that is shown by the salinity contour. The effects of upwelling on the shape of the plume are pronounced.

Surface data for several parameters are shown by Figures 1-3.

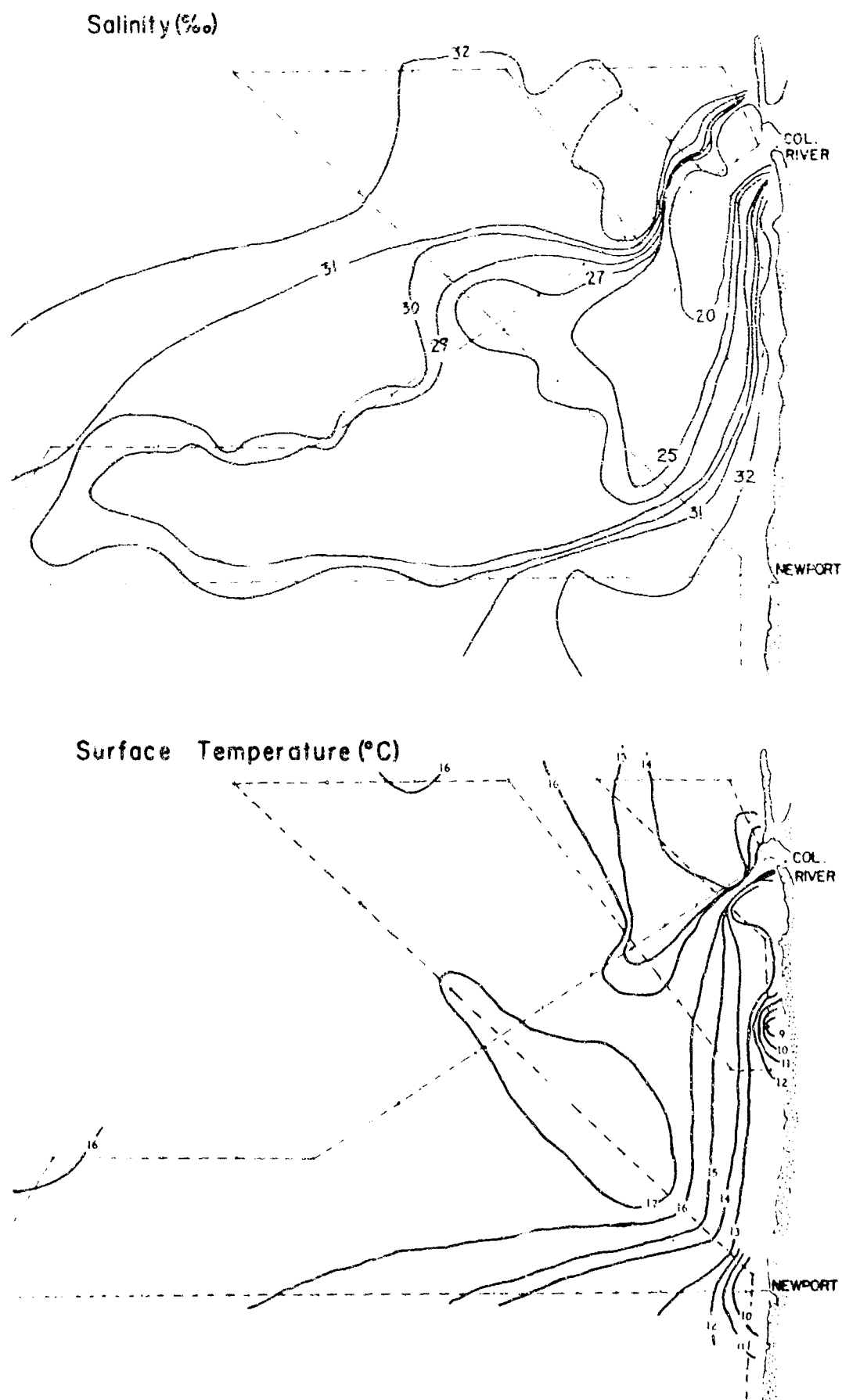


Figure 1. Salinity and surface temperature characteristics of the Columbia River plume, July 1967.

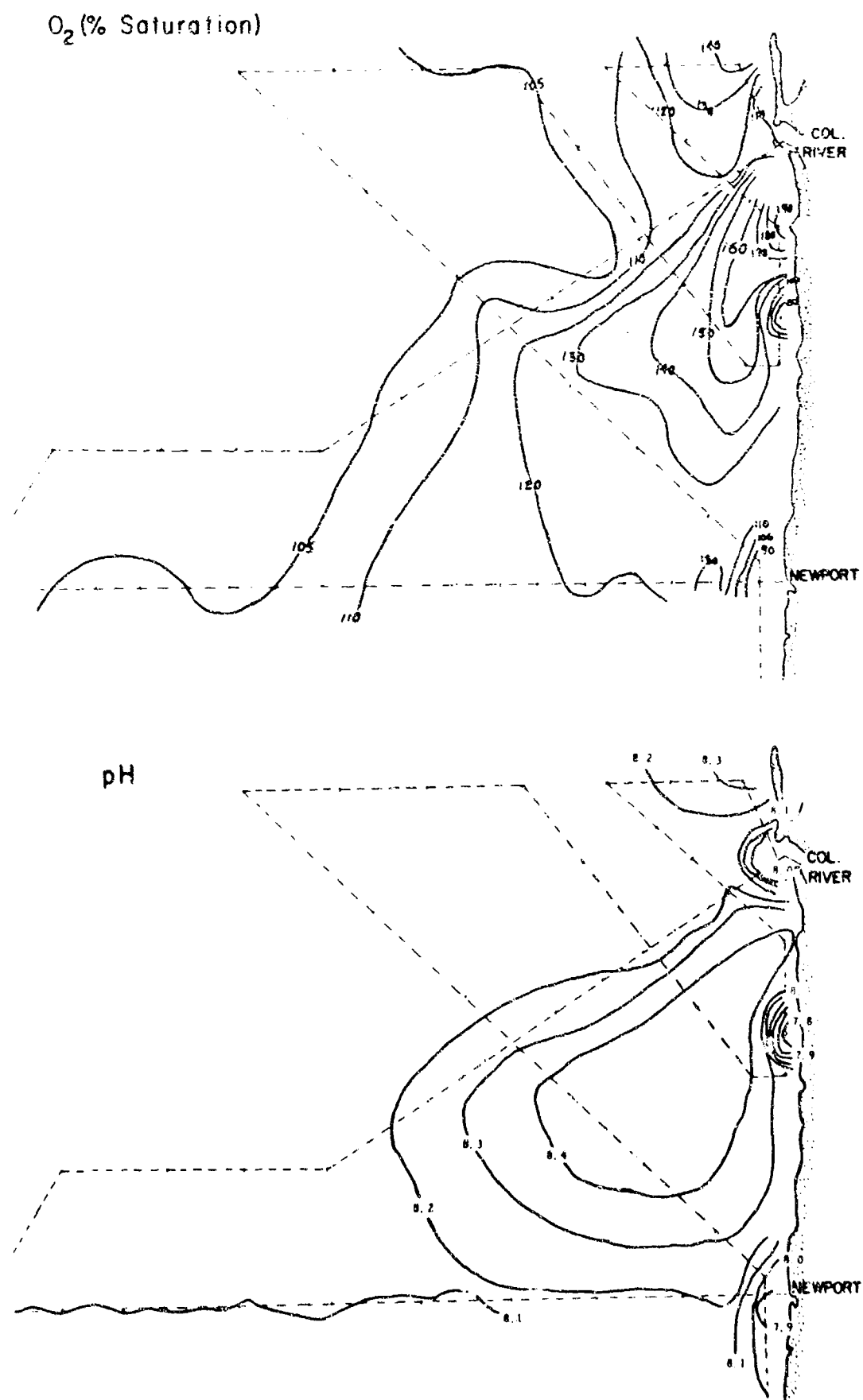


Figure 2. Oxygen saturation and pH characteristics of the Columbia River plume, July 1967.

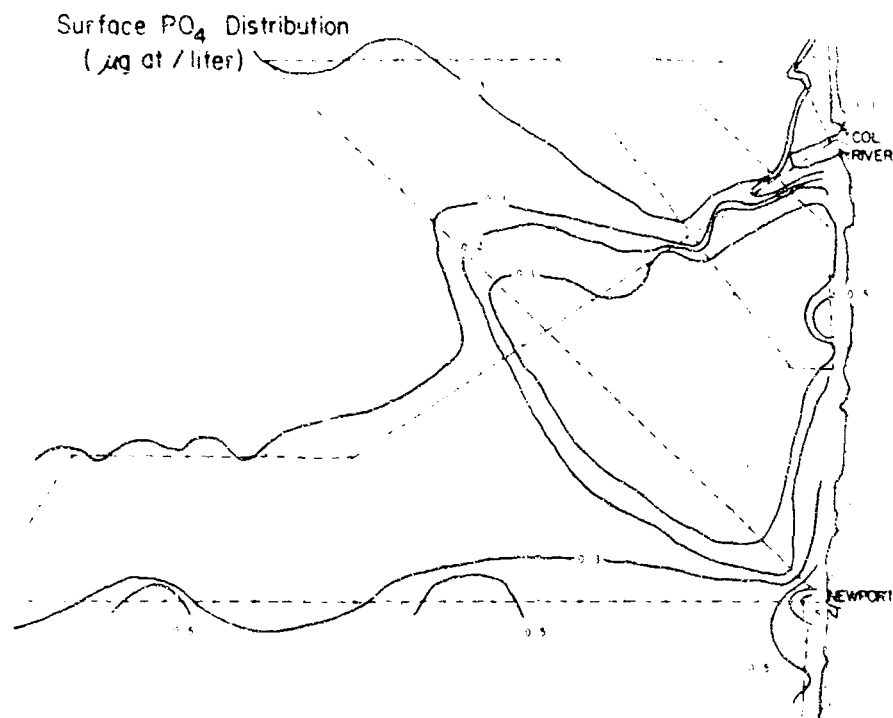


Figure 3. Surface phosphate distribution characteristics of the Columbia River plume, July 1967.

Mr. Cissell is carrying out a study of the chemical synoptics.

Dr. Sugiura and Mr. Gordon have calculated flushing times for water in the plume, examined phosphate-oxygen relationships in the plume and upwelling regions, and calculated evaporation rates based upon salinity gradients observed in the upper one meter during fair weather.

Columbia River Estuary Studies - Park, Osterberg, Catalfomo, Haertel, Kujala

A monthly sampling program at several stations in the estuary is being carried out and samples analyzed for salinity, pH, alkalinity, total CO<sub>2</sub>, and plant nutrients. The twofold purpose is characterization of the estuary relative to radioecological studies and a continuation of studies of the chemical inputs of the river into the Northeast Pacific.

YALOC-66 Chemical Work, Chemical Synoptics - Park, Erdmann, Catalfomo, Gunnings, Neal, Panshin, Connors

A study of the chemical synoptics across the Subarctic Boundary near 170° W has been published in the Journal of the Fisheries Research Board of Canada.

The effects of carbonate dissolution and oxygen consumption on the apparent pH of seawater are being examined. The influence of oxygen utilization on the apparent pH is greater than that of carbonate dissolution. The chemical parameters measured at sea (salinity, pH, alkalinity, and

nutrients) are presented along sigma-t surfaces.

Carbonic and Boric Acids - Pytkowicz, Culberson

The determination of the apparent dissociation constants of carbonic and boric acids in seawater was extended to 2° C and 1,000 atmospheres. The experiments were completed and Mr. Culberson is now writing his M.S. thesis.

Sulfate Complexes - Pytkowicz, Kester

The sodium sulfate complexes in seawater are now being studied at 22°C and 1 atmosphere by means of a glass electrode - calomel electrode couple.

Calcium Carbonate - Pytkowicz, Fowler, Culberson, Hawley

The results obtained in Liege, Belgium, (Pytkowicz, Disteché, and Disteché, in press) with aragonitic oolites were extended to calcitic foraminifera at 22° C. A manuscript is in preparation. The measurements with foraminifera will extend to lower temperatures.

Calcium Phosphate - Pytkowicz, Gates

Preliminary measurements are being made on the solubility of apatites in seawater. At present the main purpose is to develop methods for taking measurements.

## RADIOCHEMISTRY AND RADIOECOLOGY

### Water Mass Studies by Activation Analysis - Hanson, Jaske, Osterberg

Radiotracer methods have proven valuable in advection, diffusion, and stratification studies in both fresh and marine waters. It seems likely that activation analysis of stable water-borne elements should provide at least the same sensitivity, plus certain additional advantages. Most important, radioactivity need not be introduced into the fluvial or marine environment. This consideration is important since the amount of radioactivity which can be added to the environment as a tracer must necessarily be limited for radiological health reasons. On the other hand, addition of stable tracers would not have to be so severely limited; thus, larger additions are possible, making studies of a large natural system feasible.

Since natural waters contain numerous trace elements sensitive to neutron activation, chemical techniques for the separation of interfering elements from the tracer are necessary. The feasibility and the methodology of using activation analysis as a detection method for stable water mass tracers are currently being studied.

### Extraction of Zinc from Seawater - Buffo, Guthrie, Forster

Zinc from the Columbia River plume water in the 10 to 25 ppb range was separated by extraction with D. E. D. T. C. in the organic solvent M. I. B. K. The reaction is pH dependent; therefore, care must be taken to maintain a constant seawater value (7.6 - 8.2) throughout the process. A final back extraction by hydrochloric acid provides a total concentration of 30 fold over seawater concentrations and allows detection by atomic adsorption spectroscopy.

### Chemistry of Chromium - Cutshall\*, Osterberg

The tracking of  $^{51}\text{Cr}$  down the Columbia River and into the Pacific Ocean is possible due to the large excess of dichromate added as an oxidizing agent by Hanford labs in their nuclear reactors. Chromatic remains hexavalent throughout this trip and unless reduction occurs by organic matter, very little adsorption takes place on sediment particles. Ion exchange is also not important in removal of chrome from the water. A lowered pH, higher concentrations of particulate organic wastes, and increased temperature would all increase the removal of  $^{51}\text{Cr}$  by the sediments. The gathering of  $^{51}\text{Cr}$  from seawater is quantitative if a reducing agent is added prior to precipitation with ammonia and iron hydroxide.

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\* Present address: Oak Ridge National Laboratories, Tennessee.

### Iron-55 Studies - Jennings, Beasley, Forster

Iron-55 and stable iron are being measured in Pacific salmon from several stations along the west coast of North America and from Japan. The specific activity ( $^{55}\text{Fe}/\text{Total Fe}$ ) of the samples varies with species and year. Samples collected in 1964 have about an order of magnitude higher specific activity than do samples collected in 1967. Distinct differences in specific activity of different species of salmon possibly reflect both feeding habits and migration routes of the respective species.

Samples of zooplankton and benthic invertebrates from Alaskan waters and from Oregon waters are being analyzed for  $^{55}\text{Fe}$ , to augment the data on  $^{55}\text{Fe}$  in salmon.

### Radioecology Characterization of a Water Column - Joint effort by Department of Oceanography, Oregon State University, and Battelle Northwest Laboratories

The first joint effort between our laboratories and Battelle Northwest was carried out aboard the YAQUINA in June 1967. Water samples were pumped through ion exchange columns from 5 discrete depths to 5000 feet. Collection was for specific activity of fallout trace elements. Nektonic organisms were collected by IKMT throughout this water column. Phytoplankton and pigments were filtered from surface water and preserved for later determination. Benthos organisms were collected by a D. O. T. and sediments by a Smith-McIntyre grab at 3700 meters. The area of study was 350 miles west of Newport, which was outside the plume contamination.

### Radioecology of Benthic Animals - Carey, McCauley, Paul Stander, Heeter, Larsen, Forster

During this report period 199 samples, representing 46 species from 17 stations and various sediment from 7 stations off Oregon, have been analyzed for gamma-emitting radionuclides. Animals with significant amounts of  $^{65}\text{Zn}$  were analyzed for total Zn for use in computation of specific activities. Research on the radioecology of a food web including benthic invertebrates and fish is underway. Samples of benthic animals and of sediment were taken on a cooperative cruise with Battelle Northwest during June at a station 350 miles off the Oregon coast. These and other samples from the cruise are presently being analyzed by Battelle Northwest.

### Effects of $^{60}\text{Co}$ Gamma Irradiation on the Radio Sensitivity of the Brine Shrimp, *Artemina* sp. - Holton, Osterberg

A series of experiments has been performed to evaluate the effects of acute doses of gamma rays, from a  $^{60}\text{Co}$  source, on brine shrimp, *Artemina* sp. These experiments tested the ability of laboratory populations to reproduce and to maintain stable populations.

The animals were studied in three-liter population cultures by maintaining constant conditions and by feeding a standard amount of food daily, as well as by pair mating the shrimp. From the pair matings it is possible to calculate the intrinsic rate ( $r$ ) of increase, both of the control population and of the various irradiated populations.

The intrinsic rate of increase is affected by relatively low doses of irradiation, but the animals are able to maintain stable and dense populations at much higher doses under laboratory conditions. However, it is possible that, under field conditions where the populations might be subjected to more stress, the lowered intrinsic rate of increase at low doses could lead to fluctuations in the population size, which in turn could lead to extinction of the population.

An incidental result of the primary study has been an evaluation of the effects of irradiation on different stages of the life cycle of the shrimp. The irradiation of animals which have reached adult size but which do not have mature reproductive glands has provided the most useful data for this series of experiments. When irradiation is great enough to eliminate reproduction, the animals' life span is increased by about 50 percent over the control animals.

Lead-210 and Polonium-210 in Marine Organisms - Beasley, Osterberg, Forster

We are attempting to define specific activity levels of naturally occurring radioisotopes,  $^{210}\text{Pb}$  and  $^{210}\text{Po}$ , in selected marine organisms in various trophic levels. Particular emphasis is being placed on those species which might serve as a source of food for humans.

Radioecology of Marine Animals - Percy, Eagle, Larsen, Forster, Osterberg

During the past six months we radioanalyzed 116 samples of marine organisms, including deep-sea, pelagic, and benthic fauna. Trace element analysis for zinc has been completed on 260 samples. Specific activities are now being studied in benthic and pelagic animals. Precision studies are also made by separation of body parts for replicate analysis.

Uptake of Radioisotopes by Amphipods - Cross\*, Osterberg, Dean\*\*, Small

The effects of temperature, sediments, feeding, and molting on uptake and retention of several radioisotopes by a marine amphipod were examined.

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\*\*Battelle Northwest Laboratories, Richland, Washington.



Laboratory experiments indicated that Anonyx sp took up about 55 percent of the  $^{65}\text{Zn}$ , less than 10 percent of the  $^{144}\text{Ce}$  or  $^{46}\text{Sc}$ , and none of the  $^{51}\text{Cr}$  ingested in their food. Further, the amphipods obtained little radiozinc from spiked sediments whereas elimination of this radionuclide was facilitated by the presence of sediments. Increasing the temperature, feeding, and molting frequency stepped up the rate of loss of radioactivity from labeled amphipods.

Relative Specific Activity Changes with  $^{65}\text{Zn}$  Accumulation from Food and Water in Rock Fish of the Genus Sebastes - Nievaard, Forster, Renfro

We are performing a laboratory analysis of  $^{65}\text{Zn}$  uptake by rock fish to examine the relative significance of two pathways of accumulation, either by direct absorption from the radioactive seawater, and/or the uptake and assimilation from ingested food. Stable zinc was determined by atomic absorption spectrophotometry and  $^{65}\text{Zn}$  activity was determined by gamma-ray spectrometry.

Distribution of  $^{65}\text{Zn}$ ,  $^{54}\text{Mn}$  and  $^{51}\text{Cr}$  in the Tissues of the Dungeness Crab, Cancer magister Dana - Tennant, Forster

Cancer magister, known on the West Coast as the Dungeness crab, is a commercially important seafood. Since radioactivity in the Columbia River is well below any dangerous levels, it has been assumed that fish foods from the river are not dangerously contaminated. However, it has been shown that shellfish can concentrate stable elements thousands of times. By studying the concentration factors, we can make assumptions about permissible activity levels in the river.

We are dissecting crabs taken from Chinook Point, Sand Island, and Buoy 10 in the Columbia River into the following parts: carapace, carapace hair, mouthparts, leg shell, leg muscle, stomach, gills, hepatopancreas, gonads, plus occasional whole fractions, i. e. tail section.

The tissues are ashed and analyzed for radioisotopes  $^{65}\text{Zn}$ ,  $^{54}\text{Mn}$ , and  $^{51}\text{Cr}$ , which are introduced into the river water from Hanford reactors. The tissues are also analyzed for their respective total element concentrations.

The objectives of this study are to determine which tissues of the Dungeness crab concentrate the three radionuclides, and to determine the  $^{51}\text{Cr}$ ,  $^{65}\text{Zn}$  and  $^{54}\text{Mn}$  specific activities in the various crab tissues.

The study has indicated that parameters which affect the radioactive levels and specific activities of these radionuclides include: (1) metabolic demand by the tissue for the radioisotope; (2) the proximity of the tissues and the radioenvironment; (3) degree of calcification; and (4) seasonal variation.

Radiozinc Uptake in Pacific Coast Asteroides - Vermeere, Forster, Osterberg

The common Pacific coast starfish, Pisaster ochraceus, is presently being sampled from six collection sites roughly 90 nautical miles apart (from Brookings, Oregon, to Neah Bay, Washington). These animals are analyzed for radiozinc and total zinc concentrations. Maximal amounts of activity in their gonadal tissue have been found to be correlated with the ovulation cycle. Pyloric caeca (hepatopancreas), on the other hand, have high concentrations of radiozinc which are independent of ovulation time. Activities higher than 200 pCi/g dry weight have been observed for pyloric caeca in the Westport, Washington, area. This project will attempt to correlate the specific activities of starfish with the flow of the Columbia River plume and with the levels of radiozinc in their main food organism, the common mussel.

Specific Activity of Mussels Collected along the Oregon Coast - Larsen, Osterberg, Forster

Specific activities of internal parts from mussels collected along the Oregon coast during the early summer months of 1967 will be determined. Samples will be put into solution and analyses carried out. Radioactivity of  $^{65}\text{Zn}$  will be determined by gamma-ray analysis utilizing a NaI(Tl) detector coupled to a 512 multi-channel analyzer. Stable zinc analyses will be accomplished both by neutron activation and by atomic absorption; in this manner, an intercomparison between neutron activation and atomic absorption for stable zinc analysis can be accomplished.

Nearly all samples have been put into solution by first ashing and then by treating the ash with 8 N nitric acid. These samples will soon be analyzed.

We hope to study mussel size, differences in the internal parts, and geographic variation.

Radioecology of Columbia River Estuary Plankton - Haertel, Osterberg

In order that zooplankton may be radioanalyzed, methods have been devised for the separation of the zooplankton from the detritus present in the water. A monthly sampling program has been carried out in the Columbia River estuary since April 1967. Samples of zooplankton are collected at different depths and tidal stages at six stations and analyzed for species abundance, distribution, and radionuclide content. Phytoplankton samples are analyzed for standing crop, species abundance and distribution, and when possible, for radionuclide content. Samples for chemical parameters are collected at the same stations and depths as the plankton samples.

We hope to correlate the findings of zooplankton abundance and

phytoplankton abundance with nutrient distribution as well as radionuclide abundance. Initial results of radioanalysis indicate that whereas phytoplankton and detritus contain  $^{51}\text{Cr}$ ,  $^{65}\text{Zn}$ ,  $^{54}\text{Mn}$ , and  $^{46}\text{Sc}$ , only  $^{51}\text{Cr}$  and  $^{65}\text{Zn}$  are present in significant amounts in the zooplankton.

#### Columbia River Estuary Fishes - Renfro, Guthrie, Phelps

Monthly sampling of the biota is carried out at four stations in the Columbia River estuary. Concurrent measurements of various environmental parameters are also made. From these measurements, some effects of season and environment on the animal abundance and distribution can be observed. Studies of stomach contents provide insight to food habits and interspecific relationships. Finally, radioanalyses are performed to examine the effects of environmental changes and feeding habits on radionuclide content of the organisms.

#### Radionuclide Transfer Through Food Webs - Renfro, Thompson

Monthly samples of sediments, water, plants, and animals are taken from a small area within the Columbia River estuary. Analysis of these samples for radioactive and total zinc allows calculation of their specific activities ( $\mu\text{Ci}^{65}\text{Zn}/\text{g total Zn}$ ). During the summer of 1966 the Hanford nuclear reactors were shut down for a 45-day period reducing input of radioactivity to the estuary. As a result, the  $^{65}\text{Zn}$  specific activities of all organisms decreased. The rate of specific activity decline appeared to be related to the trophic level of the organism.

Figure 1 shows the results of analyses of juvenile starry flounders over a one-year period. Each point represents an individual fish and the scatter of points indicates variability among individuals. The lower graph of  $^{65}\text{Zn}$  specific activities shows a rapid decline during the period (1 August to 15 September) when  $^{65}\text{Zn}$  input to the estuary was reduced. At the rate of loss under the conditions prevailing during this period, roughly 140 days would be required for the  $^{65}\text{Zn}$  specific activities to be reduced by one-half.

CONCENTRATIONS OF  $^{65}\text{Zn}$  AND TOTAL Zn  
IN JUVENILE STARRY FLOUNDER (*PLATICHTHYS STELLATUS*)

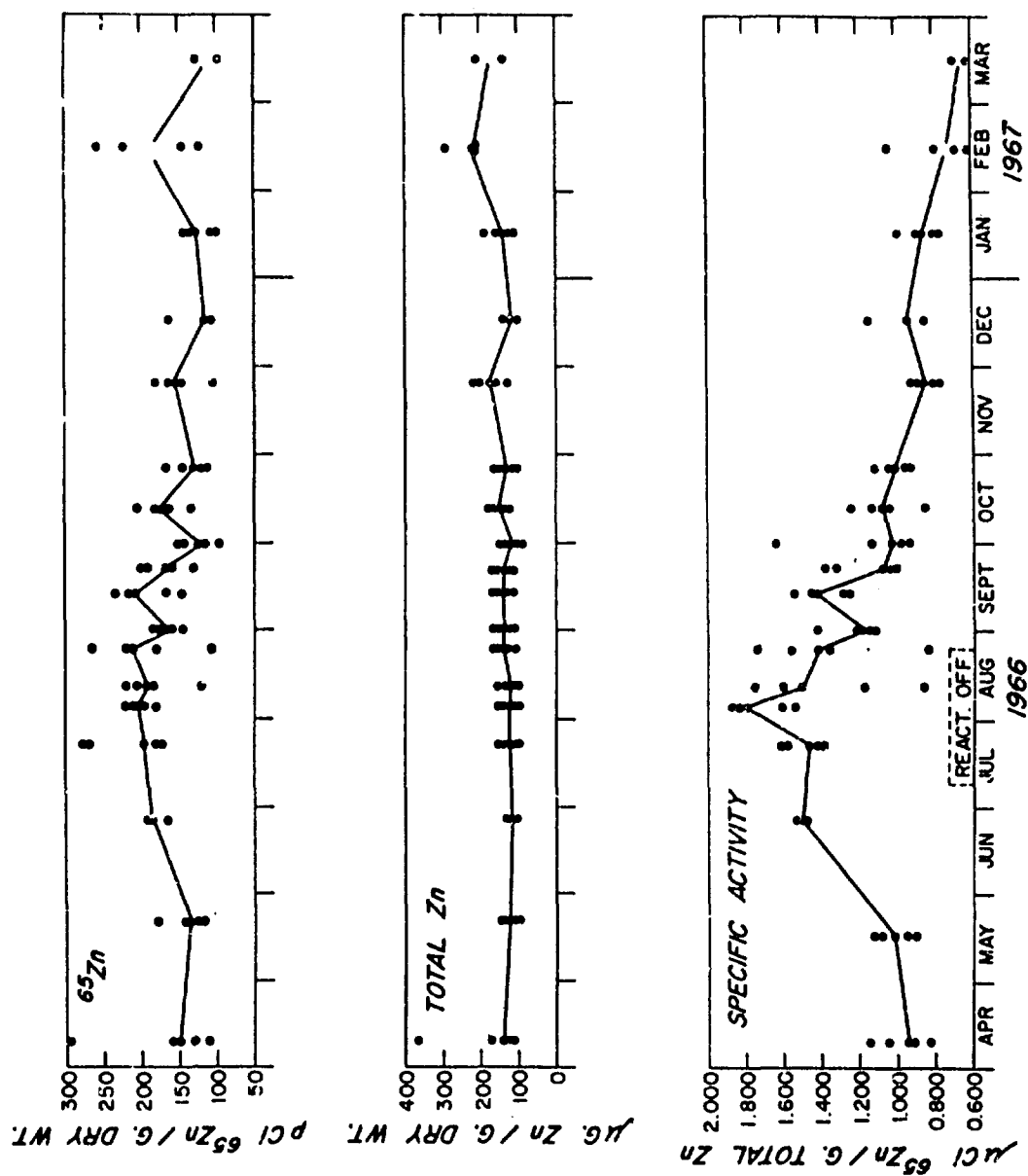


Figure 1. Results of analyses of juvenile starry flounders over a one-year period.

## BIOLOGICAL OCEANOGRAPHY

### Ecology of Oceanic Animals - Percy, Lorz, Coleman, Smiles

During the report period a total of 36 midwater trawl collections were made as a continuation of the study of depth distribution of oceanic animals. Sixteen meter-net collections were made completing this program for the present, and data are being compiled for microplankton biomass analysis.

Larval stages of fishes from midwater trawl collections are being examined for life history studies. Research on vertical migration of euphausiids is in progress. A conducting cable system of open-closing nets is being developed to facilitate this study.

### Benthic Ecology - Carey, Alspach, Hancock, Hufford

The following samples were collected from the benthic environment on four cruises during the report period: 30 otter trawl, 24 Smith-McIntyre grab, 1 anchor-box dredge, 2 beam trawl, 16 multiple corer, and 16 Fjarlie bottle water samples. Bottom photographs in conjunction with the geology group were obtained from 11 depths off the central Oregon coast. Otter trawl, grab, and water samples were obtained from both the Tillamook Head and Newport station lines. Anchor-box dredge and quantitative beam trawl samples were collected on the Newport line.

Laboratory analysis of the samples and identification of the animals continue. Papers summarizing asteroid food source and a general summary of the results of the benthic ecological research are in preparation.

### Reproduction of an Abyssal Sea Cucumber - Hufford, Carey

The study of the year-around reproductive activity of Paelepatides sp., an abyssal sea cucumber found 65 miles off Newport, is being completed. Seasonal samples have been analyzed for gonad index, egg diameter, histological state, and population size structure. Statistical studies have been undertaken to determine possible effects of size and season on reproductive state.

### Systematics of Polychaetes - Hancock, Carey

Work on the classification of the deep-sea polychaete fauna off Oregon is producing meaningful results. We were greatly aided in this effort by the opportunity to work under the guidance of Dr. Olga Hartman at the Allan Hancock Foundation in Los Angeles, California.

It is becoming apparent that our polychaete fauna from the deep sea (1000-3000 m) has generic affinities with most of the other deep-sea areas which have been studied. On the specific level our fauna exhibits a great deal of endemism. This finding adds support to the theory that the deep sea is controlled by biological rather than physical parameters and is conducive to rapid speciation.

We are finding 30-50 percent of the species present are new to science but belong to many of the characteristic deep-sea genera.

Upon completion of the taxonomic study of these worms, we are looking forward to entering the second stage of the study, that of understanding the distribution and ecological association of these polychaete worms. Hopefully we will be able to look at some of the reasons for the tremendous diversification.

#### Deep-Sea Boring and Fouling Study - Tipper, McCauley

After an initial sampling interval of 30 days (in December 1966) at a depth of 200 meters, a time-series analysis designed to study rates of bio-deterioration on a wide variety of sample materials was initiated early in January 1967. Two sample panel arrays were successfully deployed and recovered from a depth of 200 meters. Both arrays were installed at the same site and recovered at intervals of 50 and 75 days, respectively.

As a continuation of this sampling plan, seven test panel arrays were installed late in the spring 1967. Array sites were located on a transect line across the lower continental shelf and the upper continental slope west of Depoe Bay, Oregon. Lower shelf installations placed at depths of 50, 100, and 150 meters were recovered after a sampling interval of 30 days. Lower slope installations consisted of two arrays per site. One site was located at a depth of 500 meters, while a second site was located at a depth of 1000 meters. One array was recovered from each slope site at intervals of 30 and 60 days.

All five mooring systems deployed in the spring sampling period proved effective and highly reliable. A total of 10 arrays have now been successfully deployed and recovered. Detailed taxonomic and ecological analysis of the test specimens is now in progress. Early results of analysis show biological attack by marine boring mollusks on all sample arrays deployed at a depth of 200 meters or greater.

### Distribution and Ecology of Oregon Echinoids - McCauley, Carey

Ten species of echinoids are known to occur off Oregon. Three distinct bathymetric groups are recognized: Strongylocentrotus purpuratus, S. franciscanus, and Dendraster excentricus occur in shallow waters from intertidal down to about 65 meters; Strongylocentrotus echinoides occurs on the outer continental shelf; Brisaster latifrons and Allocentrotus fragilis occur on the outer shelf and the upper slope at depths of about 70-840 meters; and Aeropsis fulva, Sperosoma giganteum, Urechinus loveni, and Ceratophysa rosea are found in deep water from depths of 2090-3000 meters. Bathymetric ranges are extended for six species and geographic ranges are extended for five species.

Two additional species from the ocean floor have been collected, but a detailed study has not been made.

Brisaster townsendi is suppressed as a junior synonym of B. latifrons. Morphological characteristics cannot be used to separate the species and meristic analysis reveals a continuous gradient which includes both species as previously interpreted. Nominal B. latifrons from Asiatic waters are not the same species and probably belong to B. omstoni.

### Deep-Sea Fish Trematodes - McCauley

Six species of the genus Lepidapedon are recognized from the deep-sea fishes off Oregon. Five are completely new but the sixth has been previously reported. A manuscript describing these is in the final stages of preparation.

A study of the morphology of the genus Lepidapedon revealed that worms with short excretory bladders came from waters cooler than 10°-15° C and that worms from warmer waters had longer bladders. A literature review has revealed that this is generally true throughout the marine trematodes.

### Hydroid Parasite of Myctophid Fishes - McCormick, Laurs, McCauley

A hydroid parasite on the myctophid fishes, Diaphus theta, Tartelonbeania crenularis, and Lampanyctus lenocopsauris was identified as a species of Hydrichthys. This is the first record of a hydroid parasitizing a myctophid fish. In addition, the hydroid occasionally parasitized the parasitic copepod, Cardiodectes medusaeus, which was on the myctophids.

Assimilation of Organic Matter by Marine Second Trophic Level Grazers -  
Small, O'Connors

Techniques have been worked out to assess ingestion, assimilation, and egestion of phytoplankton cells by euphausiids and copepods. These processes can also be measured by dry weight and organic matter. Limits and variability of the cell counting techniques and ingestion measurements have been set, and curves to predict dry weight and organic matter from cell counts have been established. Use of the relatively large, unicellular diatom Ditylum brightwelli as the food organism allowed relatively simple statistical treatment of the data. Feeding experiments under different environmental conditions are now underway.

Metabolism of Zinc-65 by Euphausiids - Small, Fowler

Mr. Fowler is concluding research and beginning to analyze data on metabolism of zinc-65 obtained by euphausiids from water and from food. This work will culminate in a Ph.D. thesis. Major portions of the work were presented in May at the Second National Symposium on Radioecology in Ann Arbor, Michigan. In addition to this work, a paper is being prepared on the transfer of  $^{65}\text{Zn}$  in large concentrations by euphausiids. A condition was simulated in which a large concentration of  $^{65}\text{Zn}$  was released in surface waters in a stabilized water column. The effect of euphausiids in removing  $^{65}\text{Zn}$  from the surface pool, through vertical migrations, molting, and egestion of radioactive phytoplankton, has been assessed for summer and winter conditions in a temperate sea.

Phytoplankton Ecology - Curl, Small, Glooschenko

We are currently preparing three papers on primary production off Oregon by  $^{14}\text{C}$  estimates, diel periodicity of photosynthetic pigments, and production estimates by using an improved chlorophyll-light technique. The first study encompasses six years of  $^{14}\text{C}$  production estimates, and factors influencing this production, at a representative station off Oregon. The combined effects of insolation and upwelling are particularly significant. Mr. Glooschenko has completed his doctoral dissertation on diel periodicity of photosynthetic pigments and has elucidated cause effect relationships. The Ryther-Yentsch chlorophyll-light technique has been completely modified for use in Oregon waters. By making the three major factors in the predictive equation functions of time of day, we were able to integrate by parts over any daylight period to get a more representative estimate of primary production. Also, the assimilation number was a function of upwelling or lack of upwelling. It is believed the new equation will be useful in any oceanic condition providing certain basic data are available. The new technique appears simple enough to allow rapid estimation of primary production over broad areas.



### Photosynthetic Action Spectra of Phytoplankton Algae - Iverson, Curl

An action spectrum of photosynthesis for Skeletonema costatum (Greville) Cleve, a pelagic, marine diatom was obtained from values of photosynthetic  $^{14}\text{C}$  uptake at various wavelengths of light. Comparison of the thallus absorption spectrum with the action spectrum of photosynthesis was in accord with theoretical expectations based on Tanada's determination of the quantum yield of another diatom, Navicula minima.

### Physiological Ecology of Cryophilic Algae - Curl, Sutton

The cryophilic or "snow algae" are photoautotrophic organisms that live in a highly selective environment. They are subjected to long periods of freezing in the winter, during which time no water is available. With the advent of warmer weather they are further subjected to daily freezing, thawing, and desiccation. Because of this harsh treatment, these organisms approximately experience the expected environmental conditions on the planet Mars.

The objectives of the investigation are

1. Taxonomy and identification of cryophilic algae in the Pacific Northwest.
2. Isolation and culture of cryophilic algae.
3. Ecological measurements of physical parameters affecting the growth of cryophilic algae in the field.
4. Effect of environmental parameters on growth and photosynthesis of cultures in the laboratory.
5. Survival of cultures of cryophilic algae under environmental extremes which are likely to be encountered on Mars.

### Yaquina Bay Plankton Studies - Frolander, McCormick, Flynn

We continued to collect samples weekly from five stations in Yaquina Bay. A total of 168 Clarke-Bumpus plankton sampler tows with #6 and #12 mesh nets and 93 half-meter net tows with #6 mesh nets were taken. At each station surface and bottom water samples were collected for determining temperature, salinity, and dissolved oxygen content.

### Alsea Bay Plankton Studies - Matson, Frolander

Seasonal distribution of zooplankton from Alsea Bay is being studied. Near weekly samples have been collected at four locations in the Bay since

September 1966. In addition to zooplankton samples taken with the Clarke-Burnpus plankton sampler with #6 mesh nets, surface and bottom water samples were taken to determine salinity, temperature, and dissolved oxygen content.

Ecology of Inshore Marine Invertebrates - Hedgpeth, Conor, Kenny, Barnes, Lough, Thiess

Because of the ecological importance of temperature relations of marine invertebrates and the urgency of the need for information on present temperature regimes and possible effects of their alteration, we have during the past six months emphasized the temperature aspects of our ecology program. During the summer 1967, we established a large number of ecological time stations on rocky beaches in central Oregon. At each station a number of ecological transects of the entire intertidal zone were made, and the occurrence and numbers of the plant and animal species recorded. The height relative to mean sea level was determined by surveying methods which permit these levels to be correlated with tidal submergence and exposure data derived from a continuously recording tide gauge operating at the laboratory. We have thereby established reference stations where changes in the intertidal communities, due to any cause, can be detected by periodic resurvey of the stations. We have also studied temperature relations of certain common species of invertebrates whose habitat and level in the intertidal was established in the surveys. Temperature tolerance, both submerged in water and in air of controlled humidity, was determined for species selected for study because of differences in level of occurrence. The respiratory rate of the same species measured at different temperatures was also studied. A close correlation between tolerance, metabolic rate, and level of occurrence in limpets of the genus Acmaea was observed.

In addition, we have begun to make extensive field temperature measurements and are in the process of installing an intertidal thermometer chain connected to a multi-channel temperature recorder. This will provide the first detailed and continuous recording of temperature ever made of the marine intertidal and the first continuous seawater temperature recording attempted along the Oregon coast. We have also started following the natural reproductive cycles of a number of the species at our time stations. We have built two pilot temperature and photoperiod controlled experimental aquaria in which long term experiments on the effect of different temperatures on the reproductive cycles of marine invertebrates may be studied, and we have begun preliminary experiments with sea urchins as test animals.

Temperature not only affects the production of gametes by adults but also the survival of larvae produced at spawning. The effect of temperature on larval survival is particularly critical since the future production and replacement of populations of these short-lived species is dependent upon

survival and success of the larvae produced each year. Larvae are much more sensitive in their ecological requirements than adults, so that a temperature change which will permit adult survival and spawning may eventually eliminate a species from the area if the larvae cannot also tolerate the change. During this past summer, we began studies on the effect of different combinations of salinity and temperature on the development and survival of the larvae of an estuarine clam found in Yaquina Bay. We will continue this work by following the adult reproductive cycle throughout the year and resume the larval work during the next breeding season. This study will allow us to predict the effect of altered water temperatures in the Bay on the reproductive success of a common representative species.

#### Pycnogonida of the Antarctic Regions - Hedgpeth, McCain

This project commenced on 1 August of the present report period. This study will continue a monographic treatment of the systematics of Antarctic pycnogonids through a study of the more than 2,000 specimens accumulated through USARP and New Zealand collecting activities. These specimens have been received at the Newport laboratory and some preliminary curating and sorting done prior to their detailed taxonomic analysis, based on a computer analysis of meristic characters, as well as traditional methods of taxonomic research. Dr. McCain has studied the collections of the material previously analyzed in this program and has begun a bibliographic card file on the synonymies of the Antarctic species. On 14 October 1967 the investigators will leave Newport for the USARP Laboratory at McMurdo Sound where they will collect living material and make observations on feeding and locomotory behavior. In addition, collections in New Zealand repositories will be examined en route to Antarctica.

#### Marine Microbiology - Morita

Studies have begun on the effect of both temperature and hydrostatic pressure on bacteria isolated from the Challenger Deep and the Philippine Trench. These organisms are termed "baroduric" since they do not require pressure but can tolerate it. It appears that the ability to withstand pressure of 1,100 atm and 5°C depends upon the age of the culture.

The temperature characteristic ( $\mu$ ) has been employed to describe the difference between various thermal groups of microorganisms. Derivation of  $\mu$  is found by substituting the growth rate for the reaction rate in the van't Hoff-Arrhenius equation. A procedure was employed that allowed us to determine 10 growth rates simultaneously. We eliminated three possible sources of error which may have been important in some of the earlier work: (1) the medium could be made up in one batch and therefore would be identical

at each growth temperature, (2) the same culture could be used as an inoculum for the various growth temperatures, and (3) sufficient experimental points were used to accurately define the slope of the  $\mu$  value curve. It was found that there was no consistent difference in  $\mu$  values of mesophiles and psychrophiles.

## DEGREES GRANTED

BERGERON, Daniel J. M. S. Biological Oceanography

Thesis Title: Uptake and Retention of Zinc-65 from Food  
by Euphausia pacifica Hansen.

Major Professor: Lawrence F. Small

BOETTCHER, Richard S. M. S. Geological Oceanography

Thesis Title: Foraminiferal Trends of the Central Oregon  
Shelf.

Major Professor: Gerald A. Fowler

COLLINS, Curtis A. Ph. D. Physical Oceanography

Thesis Title: Description of Measurements of Current  
Velocity and Temperature over the Oregon  
Continental Shelf, July 1965-February 1966.

Major Professor: June G. Pattullo

CARLSON, Paul R. Ph. D. Geological Oceanography

Thesis Title: Marine Geology of Astoria Submarine Canyon.

Major Professor: John V. Byrne

CONNORS, Donald N. Ph. D. Chemical Oceanography

Thesis Title: The Partial Equivalent Conductances of Salts  
in Seawater.

Major Professor: Peter K. Weyl

CRONIN, John T. II. Ph. D. Radiochemical Oceanography

Thesis Title: Techniques of Solvent Extraction of Organic  
Material from Natural Waters.

Major Professor: William O. Forster

CROSS, Ford A. Ph. D. Radiochemical Oceanography

Thesis Title: Behavior of Certain Radionuclides in a Marine  
Benthic Amphipod.

Major Professor: Charles L. Osterberg

DAY, Donald S. M.S. Biological Oceanography

Thesis Title: Distribution of Benthic Fishes on the Continental  
Shelf and Slope of the Oregon Coast.

Major Professor: William G. Percy

DONALDSON, Henry A. M.A. Biological Oceanography

Thesis Title: Sound Scattering by Marine Organisms in the  
Northeastern Pacific Ocean.

Major Professor: William G. Pearcey

GILBERT, William E. M.S. Physical Oceanography

Non-thesis

Research Title: A Study of Seiching in Yaquina Bay, Oregon.

Major Professor: June G. Pattullo

GLOOSCHENKO, Walter A. Ph.D. Biological Oceanography

Thesis Title: The Ecological Significance of the Diel Periodicity  
of Photosynthetic Pigments in Marine Phytoplankton.

Major Professor: Herbert C. Curl, Jr.

HANSON, Peter J. M.S. Radiochemical Oceanography

Thesis Title: Vertical Distribution of Radioactivity in the  
Columbia River Estuary.

Major Professors: Charles L. Osterberg and William O. Forster

LEE, Kuo-heng. M.S. Physical Oceanography

Thesis Title: Geopotential Anomaly and Geostrophic Flow off  
Newport, Oregon.

Major Professor: June G. Pattullo

LOVEALL, Robert E. M.S. Geophysical Oceanography

Non-thesis

Major Professor: Donald E. Heinrichs

MARKHAM, John C. M.A. Biological Oceanography

Thesis Title: A Study of the Animals Inhabiting Laminarian  
Holdfasts in Yaquina Bay, Oregon.

Major Professor: Herbert E. Frolander

McKNIGHT, William R. M.A. Geophysical Oceanography

Thesis Title: A Paleomagnetic Study of Recent Cascade Lavas.

Major Professor: Donald E. Heinrichs

MESEGAR, Roderick S. Ph.D. Physical Oceanography

Thesis Title: Oceanic Vertical Temperature Measurements  
Across the Water-Sediment Interface at Selected  
Stations West of Oregon.

Major Professor: Wayne V. Burt

OLSON, Boyd E. Ph.D. Physical Oceanography

Thesis Title: On the Abyssal Temperatures of the World Oceans.

Major Professor: June G. Pattullo

- QUINN, William H. Ph.D. Physical Oceanography  
Thesis Title: Cloud Cover and Incoming Solar Radiation over  
the Equatorial Pacific.  
Major Professor: Wayne V. Burt
- RENFRO, William C. Ph.D. Radiochemical Oceanography  
Thesis Title: Radioecology of  $^{65}\text{Zn}$  in an Arm of the Columbia  
River Estuary.  
Major Professors: Charles L. Osterberg and William O. Forster
- RUSSELL, Kenneth L. M.S. Chemical Oceanography  
Thesis Title: Clay Mineral Origin and Distribution on Astoria  
Fan.  
Major Professor: Kenneth S. Deffeyes
- SEABROOKE, James M.S. Physical Oceanography  
Non-thesis  
Research Title: The Layer of No Motion in the Ocean  
Major Professor: Steven J. Neshyba
- VAN ARSDALE, Harriet A. M.S. Biological Oceanography  
Thesis Title: The Distribution of Hyperiid Amphipods off the  
Oregon Coast.  
Major Professor: William G. Percy
- VOSSLER, Donald A. M.S. Geophysical Oceanography  
Thesis Title: On the Influence of Terrestrial Heat Flow  
Anomalies on the Temperature Microstructure  
at the Ocean Floor.  
Major Professor: Gunnar Bodvarsson
- YAO, Neng-chun M.S. Physical Oceanography  
Thesis Title: Analysis of Hydrographic Techniques--A Study  
of Different Effects of Geostrophic Current  
Computations by Using Various Hydrographic  
Data Processing Methods.  
Major Professor: Stephen J. Neshyba

## FACILITIES

### Marine Science Center

#### Aquarium

The modification program of the aquarium at the Marine Science Center, Newport, Oregon, has been completed. New items include a large display tank, 14 feet in length with a capacity of approximately 2,500 gallons, and a fiber-glass reinforced plastic reservoir tank of 2,000-gallon capacity. Filtered water is now supplied to the aquarium proper, to lobby tanks for the octopus and the intertidal displays, and to the display panels. Safety features such as skidproofing for the floors and hand rails have been added.

#### Small Boat Marina

Construction of moorage adjacent to the main dock at the Marine Science Center is almost complete. Piling has been installed to protect the existing main dock from floating debris. Four float sections have been constructed and installed. Electricity and fresh water have been made available at dockside. A small dock located behind the main dock has been completed for the 33-foot PAIUTE.

Two barges (each consisting of two smaller barges joined together) have been purchased for the facility. These barges will be used to construct a 160-foot pier 9 feet wide, for the R/V CAYUSE (presently under construction) and other small ships.



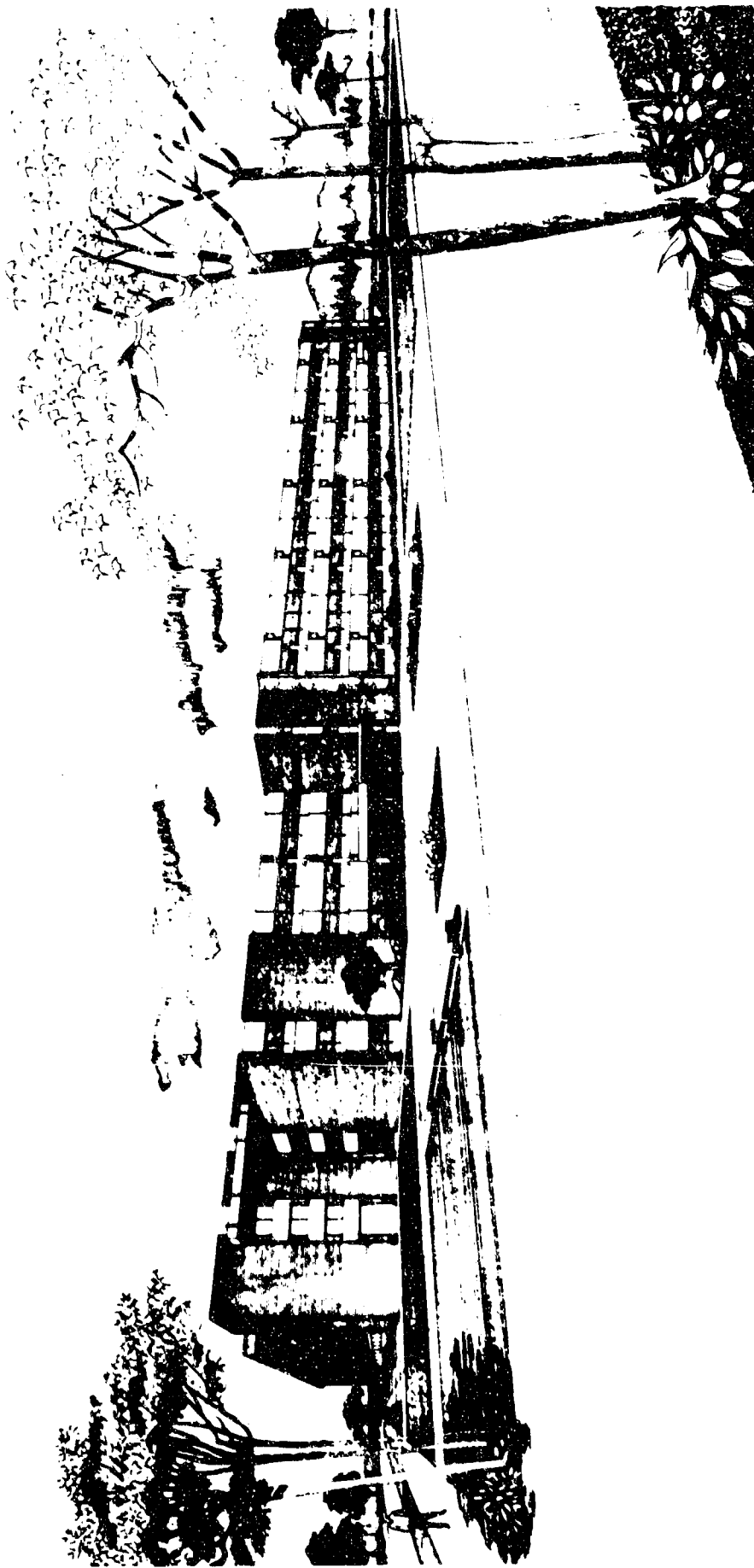


Figure 1. Architect's drawing of the oceanography building and oceanography building addition. Portion of complex at the far left is existing oceanography building.

### Oceanography Building Addition

Construction of the new oceanography building addition, Figure 1, is planned for spring 1968. The addition will contain 28,200 square feet and accommodate approximately 100 persons. Staff and students of geophysics, geological oceanography, chemical oceanography and some biological oceanographers will move into the new space upon its completion. Members of physical oceanography, biological oceanography, radiochemistry, and radioecology will utilize the present building. Scheduled completion date for the new addition is summer 1969.

### Research Vessels

#### R/V PAIUTE

The 33-foot boat, PAIUTE, has been used for estuarine and coastal work since mid 1966. Animal specimens have been collected for research, aquarium displays, and class work by the marine biologists. The PAIUTE is most useful for testing scientific equipment both at sea and in Yaquina Bay. Oceanographers have also used this vessel to investigate potential sites for scientific instrument installation.

#### R/V CAYUSE

Construction of the Research Vessel CAYUSE, Figure 2, is underway at the shipyards of Albina Engine and Machine Works, Portland, Oregon. The vessel will be 80 feet in length and will berth seven crew members and seven scientists. Cruising speed will be approximately 9.0 knots with a maximum range of approximately 4,500 nautical miles.

The CAYUSE will be equipped for all types of marine research and will operate mainly in the waters off the Pacific Northwest coast. She will fill the gap between our 180-foot deep sea vessel YAQUINA and the 33-foot coastal water vessel PAIUTE.

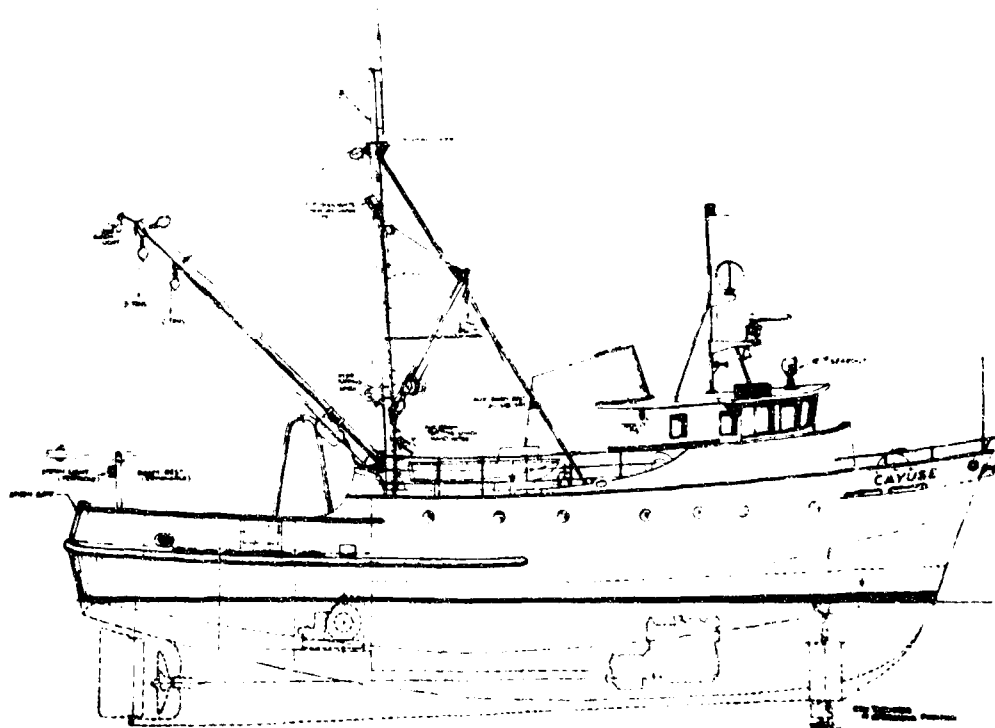


Figure 2. Profile of R/V CAYUSE

#### R/V YAQUINA

During the past year, our 180-foot Research Vessel YAQUINA has traversed 26,550 miles of Pacific water off the West Coast in 253 days at sea. A time at sea chart and track lines of individual cruises are found in Figures 3 to 5. The YAQUINA has traveled 78,700 miles at sea since her commission in September 1964. During her 745 total days at sea, she has allowed scientists to carry out all types of marine research.

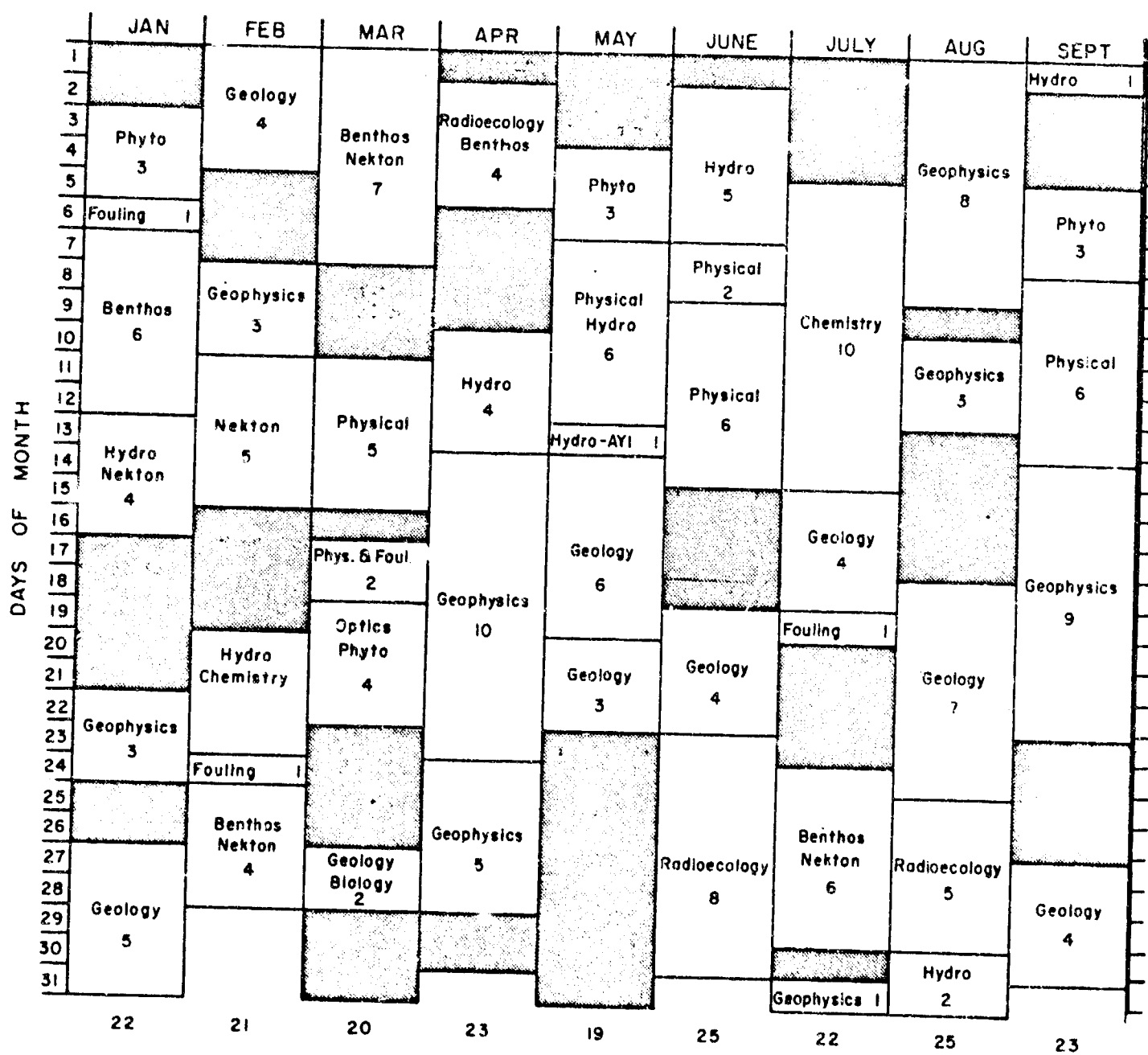


Figure 3. Time at sea - R/V YAQUINA.

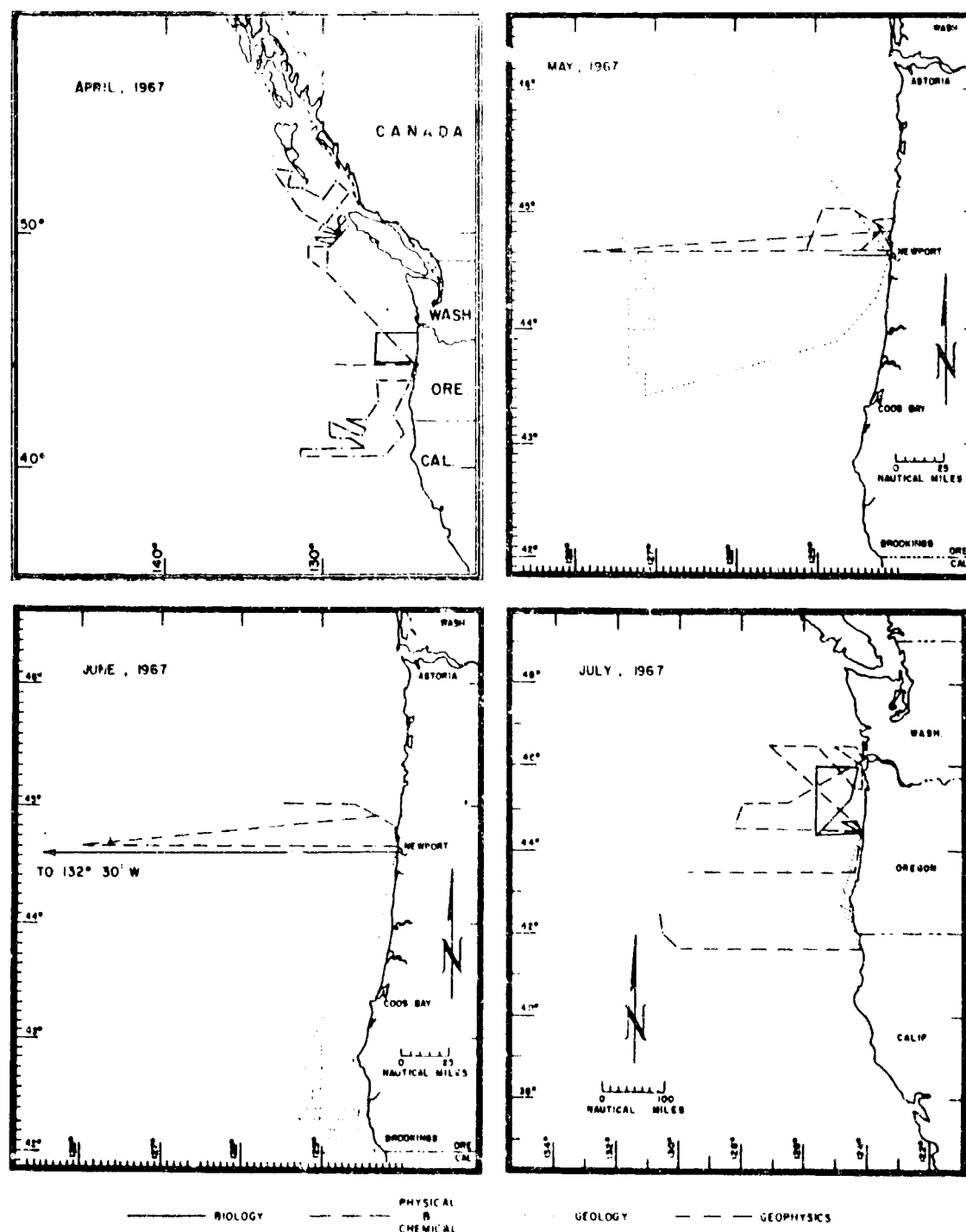


Figure 4. Cruise tracks of R/V YAQUINA, April 1967 - July 1967.

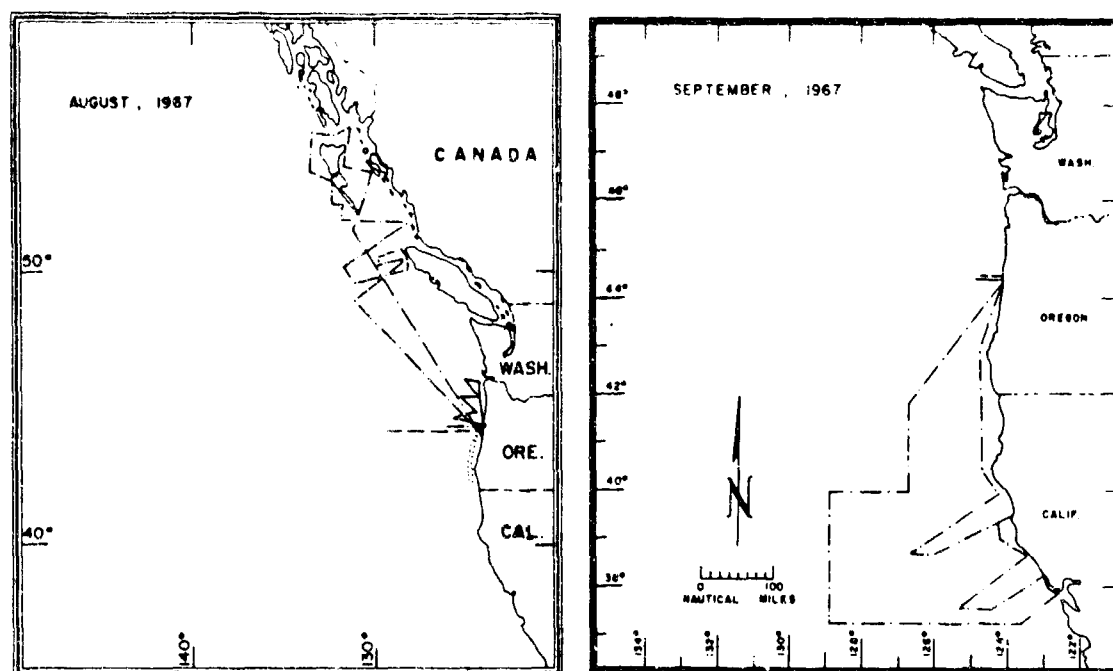


Figure 5. Cruise tracks of R/V YAQUINA August 1967 - September 1967.

## STAFF

Dr. Wayne V. Burt has been appointed Associate Dean of Research (for oceanographic programs) by the University. He came to Oregon State with a B.S. degree from Pacific College and M.S. and Ph.D. degrees from the University of California. An honorary Sc.D. degree was conferred on him in 1963 by George Fox College.

Dr. Burt was associated with Scripps Institution of Oceanography, Johns Hopkins University, and the University of Washington before joining the Department of General Science at Oregon State University in 1954. By 1959 Dr. Burt had established a graduate field of oceanography and a new department. When the new Marine Science Center at Newport, Oregon, was constructed in 1965, Dr. Burt was named director of the complex. He served the Department as Chairman for eight years.

Dr. Herbert F. Frolander has been named Acting Chairman of the Department of Oceanography. He holds a B.S. degree from Rhode Island College of Education and both an M.S. and a Ph.D. degree from Brown University.

Dr. Frolander served on the faculty at the University of Washington from 1952 to 1959. In 1959 he accepted the position of Associate Professor in Oceanography at Oregon State University. In 1965 he was promoted to full Professor and in 1966 he was named Coordinator of Marine Science Programs. During 1966-67 he served as Acting Assistant Dean of the Graduate School.

Dr. Michael S. Longuet-Higgins has joined our staff as a Professor in Oceanography. He received a B.A. in mathematics and a Ph.D. in Geophysics from Cambridge University, England. After completion of degrees, Dr. Longuet-Higgins was the recipient of a Commonwealth Fund Fellowship to study at Woods Hole and Scripps Institution of Oceanography. From 1951 to 1955 he was granted a research fellowship to work at Trinity College, Cambridge. Dr. Longuet-Higgins was Principal Scientific Officer to Deputy Chief Scientific Office at the National Institute of Oceanography, England, from 1954 to 1967. He has also served as Visiting Professor at the Massachusetts Institute of Technology, the University of California, and the University of Adelaide. In 1963 he was elected a Fellow of the Royal Society of London.

Dr. Longuet-Higgins has written more than 65 published papers, mostly on theoretical aspects of physical oceanography with particular emphasis on ocean waves and ocean currents and on statistical treatment of physical properties. He is currently working on time fluctuations in ocean currents having periods of the order of a few pendulum-days.

Dr. David Tilles arrived at Oregon State as an Associate Professor in Oceanography. He received his A. B. and Ph. D. degrees from the University of California, Berkeley, California. Natural variations of isotopic abundance of silicon was the subject of his doctoral dissertation.

Dr. Tilles has been employed as a Senior Physicist for the National Company, Malden, Massachusetts; a Research Associate for Harvard College Observatory; and a Physicist at Smithsonian Astrophysical Observatory. His research interests include geochemistry, isotope geology, cosmochemistry, geochronology, mass spectrometry, solar system physics, and sea sediments.

Dr. G. Stephen Pond joined our Department in May as an Assistant Professor in Oceanography. His B.S. and Ph. D. were earned from the University of British Columbia. His doctoral dissertation is entitled "Turbulence of spectra in the atmospheric boundary layer over the sea."

In 1965 Dr. Pond was the recipient of the National Research Council of Canada Postdoctoral Fellow. He elected to do his postdoctoral work at the National Institute of Oceanography, England, with Dr. Michael S. Longuet-Higgins. Under an exchange program of the National Research Council of Canada Academy of Science, Dr. Pond recently visited various institutions in Moscow including the Institute of Atmospheric Physics, the Institute of Oceanology, Academy of Sciences, Moscow State University, and the Institute of Oceanology in Leningrad.

Dr. William C. Renfro has been appointed Assistant Professor in Oceanography. He received his B. A. and M. A. from the University of Texas and a Ph. D. from Oregon State University. His dissertation is entitled "Radioecology of  $Zn^{65}$  in an arm of the Columbia River estuary."

Before coming to Oregon State, Dr. Renfro was employed as a Fishery Research Biologist for the U. S. Bureau of Commercial Fisheries and as a Marine Biologist for the Texas Game and Fish Commission. He was a Senior Weather Observer for the U. S. Air Force from 1951-1952 and a Combat-Ready Navigator for the U. S. Tactical Air Force from 1953-1956. His research interest is in marine radioecology.



Mr. Richard W. Couch has been appointed an Instructor in Oceanography. He earned a B.S. degree from Michigan State University, an M.S. degree from Oregon State University and is now completing requirements for a Ph.D. in geophysical oceanography.

Mr. Couch has worked as a research staff member for two industrial corporations, General Dynamics/Electronics and Eastman Kodak Company. He also has worked on electronic meteorological equipment and radiosonde and telemetering devices for the United States Army. His interests are in earthquake seismology, marine gravity, and magnetics.

Dr. William H. Quinn, new Research Associate in Oceanography, received his A.B. from Colgate University, A.M. from the University of Missouri, meteorology training at New York University, M.S. from U. C. L. A. in Oceanography, and recently a Ph.D. from Oregon State University. "Cloud cover and incoming solar radiation over the equatorial Pacific" is the title of his doctoral dissertation.

Dr. Quinn served 22 years with the U.S. Air Force before returning to graduate school to complete requirements for the Ph.D. His vast experience as a meteorologist and climatologist with the Air Force substantially qualifies him for our air-sea interaction program. He is continuing his research on radiation phenomena associated with the equatorial Pacific.

Miss Ute E. Görner, Research Associate, traveled from Germany to become part of our research staff. She holds both a Vor diplom and a Haupt diplom from the Universitat Hamburg. Her studies at Hamburg were in the fields of meteorology, physics, oceanography, and geophysics.

Miss Görner has been employed at the Universitat Hamburg, Saclant ASW Research Center and recently as a meteorologist at the Berlin-Tempelhof Airport. She will assist Dr. Pond with his air-sea interaction studies.

Dean Wayne V. Burt began a five-month sabbatical leave on 1 September 1967. He will spend much of his time on research at Scripps Institution of Oceanography.

Dr. Peter Dehlinger has extended his leave of absence to 1 September 1968. He is serving as Head of the Geophysics Group, Ocean Science and Technology, Office of Naval Research, Washington, D. C.

Dr. Herbert F. Frolander spent six weeks, from mid-June through July, with the Department of Oceanography, University of Hawaii. He acted as an adviser to their biological science program as well as teaching an introductory course in oceanography.

Dr. Charles L. Osterberg is currently serving as Marine Biologist for the Environmental Sciences Division of Biology and Medicine, Atomic Energy Commission, Washington, D. C. He will return to the Department in the spring of 1969.

Dr. Kiho Park is spending a sabbatical leave at the Department of Chemistry, Woods Hole Oceanographic Institution. Dr. Park and Dr. F. A. Richards of the University of Washington are working together on a chemical oceanography textbook. He will return to the campus in December.

Dr. William G. Percy began a nine-month sabbatical leave on 1 September 1967. He will be engaged in research at the Fisheries Oceanographic Center, La Jolla, California.

Dr. Roderick S. Mesecar completed the requirements for the Ph. D. in oceanography this past summer. His dissertation is entitled "Oceanic vertical temperature measurements across the water-sediment interface at selected stations west of Oregon."

Dr. Kenneth Deffeyes has joined the Geology Department of Princeton University, Princeton, New Jersey.

## VISITING SCIENTISTS

April	Dr. George Kline, University of Pennsylvania
May	Mr. Feenan Jennings, Office of Naval Research, Washington, D. C.
	Dr. John Lyman, Office of Naval Research, Washington, D. C.
	Mr. Marston Sargent, Office of Naval Research, Washington, D. C.
	Dr. Robert Wall, Office of Naval Research, Washington, D. C.
	Dr. Peter Dehlinger, Office of Naval Research, Washington, D. C.
	Dr. Neil Maloney, Universidad de Oriente, Cumana, Venezuela. "The geology of the continental margin of Venezuela."
	Dr. Dan Weill, Geology Department, University of Oregon. "Deducing the temperature of formation from features in plagioclase crystals."
June	Mr. Peter H. Wyckoff, Program Director for Weather Modification, National Science Foundation, Washington, D. C.
	Dr. Yoshio Sugira, Visiting Chemical Oceanographer, Meteorological Research Institute, Tokyo, Japan.
	Mr. Walter Smith, Office of Naval Research Representative, Seattle, Washington.
	Mr. James Wakefield, Weather Bureau, Portland.
	Mr. A. Larry Zimmerman, Public Service Operations Meteorologist, Weather Bureau, Salt Lake City, Utah.
July	Dr. Edward Chin, Texas A & M University.

Dr. Richard Backus, Woods Hole Oceanographic Institution,  
Woods Hole, Massachusetts.

Miss Mary Johrde, Program Director for Oceanographic  
Facilities (Acting), Oceanography Section, National  
Science Foundation.

Dr. Tjeerd H. Van Andel, Scripps Institution of Oceano-  
graphy, La Jolla, California. "The future of marine  
geology."

Dr. Robert Paquette, General Motors Defense Research Labor-  
atories, Santa Barbara, California.

Dr. Eugene Corcoran, Facilities and Special Programs,  
Biological and Medical Sciences Division, National  
Science Foundation.

Professor Vassili Kiortsis, Director of the Zoological Labor-  
atory and Museum, University of Athens, Greece.

Mrs. Nell Frazer, Atomic Energy Commission, Richland,  
Washington.

Mr. Max Silverman, Scripps Institution of Oceanography,  
La Jolla, California.

Mr. Arnold Joseph, Atomic Energy Commission, Washington,  
D. C.

Dr. James Murray, Atomic Energy Commission, Washington,  
D. C.

Dr. Charles Osterberg, Marine Biologist for the Environmental  
Sciences Division of Biology and Medicine, Atomic Energy  
Commission, Washington, D. C.

Dr. Edward D. Goldberg, Scripps Institution of Oceanography,  
Atomic Energy Commission Review Panel.

Mr. James Stewart, Scripps Institution of Oceanography,  
Diving Office. "Man in the sea."

Mr. Harry Bourne, United Kingdom Scientific Mission,  
Washington, D. C.

- August      Dr. J. Allen Scott, National Institutes of Health, Bethesda,  
                 Maryland.
- Miss Susan Bershard, National Oceanographic Data Center.
- Mr. Aubrey W. Pryce, Office of Naval Research, London  
                 Office. England.
- Dr. Patrick Squires, Department of Meteorology, University  
                 of Nevada, Reno. Director, Laboratory of Atmos-  
                 pheric Physics, Desert Research Institute, University  
                 of Nevada.
- September   Professor Y. Kitano, Water Research Laboratory, Faculty  
                 of Science, Nagoya University. "The effect of organic  
                 matter on calcium carbonate precipitation."
- Mr. Robert Abel, Director of Sea Grant Programs, National  
                 Science Foundation, Washington, D. C.
- Dr. Leroy H. Fisk, Department of Biology, Oregon Technical  
                 Institute, Klamath Falls, Oregon.

## VISITING SCIENTISTS ABOARD R/V YAQUINA

March	M. Blything	J. Gratsch	R. Kay	D. Reber
	M. Brown	D. Hamilton	M. Love	R. Sinn
	H. Erickson	A. Herrin	D. Ohde	D. Tash
	M. Freed	F. Hirashima	P. Poppleton	W. Taylor
				D. Willig

Oregon State University Academic Year Institute Group. Cruise 6703, Biology-Geology, Carey, Kulm, Fowler.

May Mr. J. Bode, University of Oregon. Cruise 6705-B, Buoy, Hydro, Smith.

June Mr. D. Edwards, Battelle Northwest Laboratories, Richland, Washington. Cruise 6706-E, Radioecology, Forster.

Mr. C. Jenkins, Battelle Northwest Laboratories, Richland, Washington. Cruise 6706-E, Radioecology, Forster.

Mr. G. Rieck, Battelle Northwest Laboratories, Richland, Washington. Cruise 6706-E, Radioecology, Forster.

Mr. E. Wundling, Battelle Northwest Laboratories, Richland, Washington. Cruise 6706-E, Radioecology, Forster.

July Dr. Yoshio Sugiura, Meteorological Research Institute, Japan. Cruise 6707-A, Chemical-Physical, Park.

Dr. E. Clifton, U. S. Geological Survey, San Francisco, California. Cruise 6707-B, Geology, Kulm.

Dr. R. Hunter, U. S. Geological Survey, San Francisco, California. Cruise 6707-B, Geology, Kulm.

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